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The Use of a Magnetic Stirrer in the Determination of the Salinity of Sea Water.

By

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THE international method of determining the salinity of sea water which is recognized by all laboratories as the standard procedure is due to Oxner and Knudsen[1]). It involves a titration with silver nitrate solution, using potassiun chromate as indicator, and requires thorough hand stirring of the solution and grinding of the precipitated silver halide by a rubber-tipped rod to minimize occlusion of chloride ions. With this method, it was found that the number of salinity determinations which a trained operator could carry out in one day was approximately 25 to 30, but when attempts were made to increase this output, results became unreliable and this was ascribed in part to the tiring nature of hand stirring. The use of a mechanical stirrer (Townson and Mercer Magnetic Stirrer) was therefore considered, and in order to show that salinity results would not be affected significantly by the adoption of this apparatus a comparison was made of the results obtained by hand and mechanical stirring. Only one other minor modification of the Oxner-Knudsen technique was necessary; a 250 ml. beaker was used for titration with the mechanical stirrer instead of a white porcelain basin.

The salinities of various samples of sea water were determined by both the hand stirring method and the mechanical stirring method. Titrations were done in triplicate by Operator A, in duplicate by

[1]) Oxner, M., and Knudsen, M. "Manuel pratique de l'analyse de l'eau de mer. I. Chloruration par la méthode de Knudsen". Bull. Comm. Internat. Explor. Mer Médit., 3. Monaco, 1920.

Operator B, and singly by Operator C. The resulting salinities are tabulated below:—

Table 1. Operator A.

Sample	Hand Stirring			Mechanical Stirring		
1	34·39	34·40	34·41	34·41	34·42	34·41
2	34·12	34·11	34·11	34·10	34·11	34·13
3	34·12	34·14	34·12	34·11	34·14	34·11
4	34·49	34·52	34·52	34·49	34·50	34·52
5	32·75	32·75	32·76	32·75	32·76	32·74
6	34·78	34·78	34·76	34·75	34·78	34·77
7	34·87	34·88	34·89	34·87	34·86	34·89
8	34·84	34·84	34·83	34·82	34·84	34·82

Table 2. Operator B.

Sample	Hand Stirring		Mechanical Stirring	
9	35·02	35·01	35·00	35·00
10	35·01	35·00	35·00	34·99
11	35·09	35·11	35·09	35·13
12	35·19	35·19	35·18	35·19
13	35·11	35·10	35·08	35·10

Table 3. Operator C.

Sample	Hand Stirring	Mechanical Stirring
14	34·42	34·41
15	34·17	34·14
16	34·20	34·21
17	34·55	34·53
18	32·81	32·80
19	34·81	34·82
20	34·90	34·91
21	34·86	34·86

From these tables may be calculated the following statistics:—

	Table 1	Table 2
Standard deviation of hand stirring method	0·010	0·008
Standard deviation of mechanical stirring method	0·014	0·015
Variance of hand stirring method	$1{\cdot}083\times10^{-4}$	$0{\cdot}7\times10^{-4}$
Variance of mechanical stirring method	$1{\cdot}875\times10^{-4}$	$2{\cdot}2\times10^{-4}$
Degrees of freedom	16	5
Variance ratio	1·73	3·14

The differences between the estimates of the standard deviation of the mechanical stirring method and those of the hand stirring method, if real, are of no practical significance and the fact that the variance ratios lie between the 40 % and 10 % significance levels shows that they are not statistically significant.

Other statistics calculated from the tables are:—

Analysis of Variance — Table 1.

Source of Variance	Sums of Squares	Degrees of Freedom	Mean Squares
Between samples	20·121267	7	—
Between methods	0·000133	1	0·000133
Inter-action	0·000567	7	0·000081
Residual	0·004733	32	0·000148

Analysis of Variance — Table 2.

Source of Variance	Sums of Squares	Degrees of Freedom	Mean Squares
Between samples	0·096570	4	—
Between methods	0·000245	1	0·000245
Inter-action	0·000430	4	0·000108
Residual	0·001450	10	0·000145

Table 3.

Variance of difference	$2{\cdot}29\times10^{-4}$	Standard deviation of mean difference	$0{\cdot}53\times10^{-2}$
Mean difference	$0{\cdot}5\times10^{-2}$		

In both analyses of variance neither the inter-action nor the between-methods variance is significantly greater than the residual, indicating that there is no systematic bias in the mechanical stirring method, nor does the difference between the methods for individual samples exceed what might be expected from the magnitude of the residual variance. For Table 3 the *t*-test indicates that the mean difference $0{\cdot}5 \times 10^{-2}$ does not differ significantly from zero, i.e., that there is no systematic bias in the mechanical stirring method.

Acknowledgments.

Our thanks are due to Mr. E. C. Fieller, Ministry of Supply, for appraisal of the results of the statistical analyses, and to the Government Chemist for permission to publish this paper.

Summary.

The use of a magnetic stirrer instead of hand stirring in the determination of salinity in sea water by the Oxner-Knudsen method does not alter the results significantly; it reduces fatigue and increases the output from approximately 30 to 40 determinations per operator per day.

Fluorescent Microscopy in Marine Microbiology.

By

E. J. Ferguson Wood.

THE importance of heterotrophic bacteria in marine environments, especially in the food chain, has long been stressed by ZoBell (cf. ZoBell, 1946), and it has gradually become evident that other heterotrophic micro-organisms may be important as food for marine invertebrates, and even for smaller vertebrates in certain environments. The difficulty has been to separate heterotrophic from autotrophic micro-organisms and so determine their relative importance. Culture methods for heterotrophs in the presence of bacteria usually result in the isolation of the latter on account of their shorter generation time, the only exception being such organisms as *Euplotes* and other ciliates which feed on bacteria. Lewin (1953) has succeeded in isolating in pure culture heterotrophic diatoms, which nevertheless possess chlorophyll. However, it is obvious that culture methods such as she uses cannot readily be adapted to give the quantitative picture required for ecological work.

While the estimation of chlorophyll by spectrophotometry gives a useful figure which can be related to total energy derived from photosynthesis, it tells us nothing of the relationship between photosynthesis and heterotrophy among micro-organisms. This relationship is important in that every additional link in a food chain means a net loss of energy, and if colourless flagellates, ciliates, or bacteria lie between the photosynthetic organisms and organisms higher in the chain, the values of productivity derived from chlorophyll estimation must be reduced accordingly by an additional efficiency factor.

Microscopic examination of marine material by direct visual light is difficult in many cases because a number of the smaller organisms are in contact with or adsorbed on detrital and other particles and cannot be distinguished. Moreover, it is difficult to tell in many cases whether they contain chlorophyll, especially in the case of the smaller flagellates.

By making use of the fluorescence of chlorophyll (Tchan, 1953), it is, however, possible to count the chlorophyll-bearing organisms with accuracy and speed. Rouschal and Strugger (1943) described a method for the direct observation of bacteria in soil by staining them with a $^1/_{5000}$ aqueous solution of acridine orange, and observing them through a fluorescence microscope. These authors state that living organisms fluoresce green and dead organisms bright red. A combination of the two techniques gives excellent results.

The writer uses the following method:—

Freshly collected material is divided into two aliquots. One aliquot

is placed on a microscope slide, and viewed through a fluorescence microscope. The source of illumination is a Zeiss fluorescence lamp with an S 80 mercury high-pressure burner. The filter system consists of a blue-purple Schott BG 12 attached to the condenser unit (which affects mainly the lines at 366, 405, and 436 μ of the burner's spectrum), and an orange check filter OG 5 (Wratten G 15) placed in the eyepiece. Paraffin oil is applied between the condenser and the slide to give maximum illumination. In this system, the chloroplasts fluoresce bright red on a blue-black field and can be counted easily and rapidly.

The other aliquot is mixed with equal quantities of $^1/_{2500}$ acridine orange in distilled water, and after about 60 seconds, placed on a slide and examined. Protoplasmic material fluoresces green, while the chloroplasts fluoresce bright red. However, the background of dead cells and detrital material is also red, so the unstained slide is needed. Care is required to distinguish between the cells and portions of still living, partly disorganized matter such as algal fragments.

With the chlorophyll fluorescence, diatoms can be readily distinguished as well as dinoflagellates, flagellates down to 1 μ in length, blue-green algae, zoospores of the chlorophyceae, etc., while the acridine orange fluorescence allows one to see the bacteria, non-pigmented flagellates, ciliates, and even nematodes and crustaceans. Diatoms give a most beautiful picture with green protoplasts and red chloroplasts, so that structure as well as form can be observed in colour in the living material.

The author and his colleagues are now applying the new method to counts of organisms in estuarine muds, both bottom muds and those carried into special containers by turbulence in the intertidal zone. Where only one to a few organisms can be seen with certainty in direct white light or by phase contrast, ten to fifty have been counted by the fluorescence technique, and a little practice allows one to differentiate the organisms quite well.

The method works equally well with fresh plankton tows, but preserved material is useless, for a number of reasons. It is necessary to have a light source of high intensity, not necessarily a mercury arc, but solutions of cuprammonia and a disk of Wratten G 15 gelatine filter can be substituted for the more expensive set-up described above. However, these economies can result in the waste of considerable time, which is always precious in routine investigations. The microscope used is a Zeiss high-power binocular with achromatic objectives and an Abbé condenser, but any good research microscope will suffice.

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The Efficiency of Drift-Nets.

By

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TO decide which fishing gear is preferable in a certain fishing industry, it is necessary to compare the expenses occurring with, and the proceeds resulting from, the different types of gear available. Such comparisons are needed when new fishing methods are developed, as, for instance, pelagic trawling, but investigations of older methods may also be useful. For instance, comparisons have been made between ring-nets and drift-nets, gill- and seine-nets, large trap-nets and trawls, especially with regard to their profitableness. However, it is possible that other points of view, such as the supply of new material for manufacturing the gear, the cost of conversion to new methods, or the labour situation, may be the deciding factor and prevent what is actually a more efficient gear from being used in place of the existing type.

In addition to comparison of the different types of gear, it is perhaps more often necessary to compare the yields of nets of the same type but of different design. In some cases this difference may relate only to the size of mesh. The latter problem has been much to the fore in sea fisheries during recent years, particularly in connexion with conservation measures.

Numerous comparative fishing tests have been carried out between trawling gear, both of the same and of different design, with various sizes of mesh, particularly in the cod-end. Comparison between the fishing output is then made not only in relation to the total catch, but also to the size of the individual fish taken by the gear. The main object of these tests is to establish minimum widths of mesh in the interests of conservation. The International Council for the Exploration of the Sea has set up for that purpose a special Committee on Comparative Fishing, which deals with the trawl fisheries.

In recent years another reason for carrying out tests with gear of the same fishing principle and design is the use of new kinds of material

for the net. It was found at an early stage in the experiments that the efficiency of a fishing gear depends not only on its design and mesh-size, but on other properties also, most of which have not yet been studied and which may change when different materials are used for the net.

In practice the term "efficiency" is used to compare the outputs of two sets of fishing gear. All that is indicated by the efficiency, however, is that the output of one set of gear is more or less than that of another. As Rümmler (1954) has pointed out, "efficiency" is not a precisely defined standard of measurement. In scientific statements, the "efficiency" of a gear under test is expressed as a percentage of the output of a control net. This is by no means a satisfactory manner in which to define efficiency. The term is only useful as a standard if instead of referring to the outputs of individual nets, it can be based on the proportion which a certain fishing gear can take from a fish shoal of known size. Such figures are difficult to obtain, although they do in fact underlie numerous investigations of the fishing rate, which depends on fishing intensity and efficiency. It seems likely that owing to the development of echo-sounders for detecting fish shoals and underwater television, a better estimate of the relation of the catch to the fish population will be possible in the near future. At present definitions of efficiency are confined to statements such as that a fishing gear achieved good or bad results, according to whether the shoals detected were large or small. For the time being, one has to operate with a measurement of efficiency which is relative and which changes its point of reference.

Investigation of the Efficiency of Gill-Nets.

Whereas many papers exist on the efficiency of trawls in sea fisheries, fewer studies have been made of other gear. The work on gill-nets, which is so important for many aspects of sea fisheries, has been carried out mainly in relation to freshwater fisheries. The importance of the careful handling of the fish caught by gill-nets and the possibility of selecting the fish by varying the mesh-size are particularly emphasized in these papers. One of the most impressive suggestions, originally made by Wagler in connexion with the *Coregonus* fishery in the lakes of the Bavarian Alps, is to use for each lake special mesh-sizes related to the fish population concerned, and to abstain from making general regulations on mesh-size, as is usually done.

The meshes in gill-nets should be of such dimensions that fish of commercial size become entangled by their opercula when they try to escape. This does not imply that only fish of a specific size are caught. The size of the fish taken varies according to the population. A graph of the quantity of the fish caught at each length exhibits a curve with a distinct maximum at certain sizes. The rising part of the curve is steeper than the falling, because relatively more large fish are sometimes caught by the net, while the smaller ones always escape (Havinga and Deelder, 1948).

Besides the size of mesh, adjustments and dimensions of the gear, the

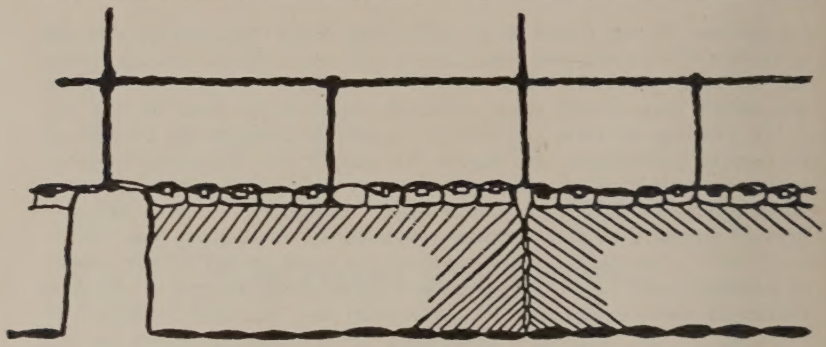

Figure 1. The distribution of the catch in herring drift-nets. Zones of low efficiency are hatched. The space between two "quartels" is shown on the left.

factors which determine the fishing output of a gill-net need only be mentioned in passing. They include the strength of the twine used (tension and thickness of the twine), the softness of the (possibly preserved) netting material and its odour, colour, and visibility (v. Brandt, 1953).

By using gill-nets of the same type and differing only in mesh-size an attempt has been made to ascertain the actual percentage size-composition of the shoals — for instance, of herrings. However, this can only be done if a number of nets placed in juxtaposition take uniform quantities. Attempts have also been made to assess for herring the effectiveness of gill-nets of the same type but of different material. This too is only possible when gill-nets placed in juxtaposition operate completely uniformly. To enable these two tests to be carried out it is necessary to know the efficiency of the conventional gill-nets used in herring fisheries. Only when the actual distribution of the catch in the control nets is known is it possible to decide whether the variations in the nets under test occur in the usual manner or whether they depend on the particular nature of the net.

Baranov (1939) found that the various sections of a single gill-net do not catch uniform quantities, especially if the net is set in a curve. Differences also occur between the fishing yields of the upper and lower parts of a net.

However, gill-net fishing is not usually carried out with a single net, but varying numbers of single nets are united in a series to form a "fleet". These single nets are attached to one another more or less closely. In the German herring drift-net fisheries in the North Sea, with which the present study is mainly concerned, over 100 nets are used in a fleet. Ten or twenty nets are attached closely to one another and form a "quartel". The quartels are separated from each other by a small interval, called the "Länge".

The question is then, Can the nets under test be inserted at any place in the fleet? What factors must be taken into consideration in

deciding this? The fleet is a complete unit and from practical experience it may be expected that the behaviour of a single net will be the same as that of the whole fleet. This, however, does not imply a uniform efficiency in all sections of a single net as well as in the whole fleet of nets. Baranov (1939) refers to the currents in the sea and the wind as being the most important factors affecting the efficiency of a fleet of nets. The current, assisted by the sinkers, contracts the nets and hampers fishing. The wind, however, in exerting a pressure on the vessel from which the fleet of nets is shot, tends to stretch the net out. Baranov's observations were made on a herring drift-net fishery. The information given below refers to a drift-net fleet used in the German herring fisheries in the North Sea.

Efficiency of the "Sinknetz" [1]) Fleet in Herring Drift-Net Fisheries.

German drift-net fishermen have gained by experience a general idea of the efficiency of the drift-net fleets used in herring fisheries. They know that the fleet may take different quantities of herring in different parts of the net. Catches may be large only in the last nets of a fleet, or after "full" nets at the beginning of the haul, the remainder may be found empty.

Before the quantitative results are discussed, it may be mentioned that the German drift-net fishery uses two types of net — the "Scotch", in which the nets are floated up from the warp, and the German "Sinknetz", in which the nets are suspended from the warp (see Schnakenbeck, 1953). The investigations now to be discussed refer to fleets of the latter type.

Experiments made with drift-nets manufactured of new kinds of material showed that the efficiency of a single net inserted into a fleet of control nets did not vary from that of the conventional nets on either side. When, however, several such trial nets made of the new material were placed in juxtaposition as a part of the fleet, it sometimes happened that they completely failed (v. Brandt, 1954 a). The explanation of this must be in the first case that the behaviour of a single trial net in the fleet of more than one hundred control nets depends on the behaviour of the neighbouring nets. When several trial nets of the same kind are placed together in the fleet of control nets, on the other hand, they operate as a complete unit, possibly differently from the control nets; they may even be inefficient and adversely affect the control nets in their vicinity.

It follows therefore that herring drift-nets made of new material or preserved by a new method cannot be tested singly in a fleet of conventional nets. It is necessary that fairly large sections of a drift-net fleet, if not the whole fleet of nets, should consist of the nets to be tested. The longer the group is, the better can it be ascertained whether they behave correctly and whether they are suited to their purpose.

[1]) i.e., nets suspended from the warp.

For financial reasons, however, it will usually be necessary to use as few trial nets as possible. These two points of view contradict each other. If the trial nets occupy a large part of the fleet, the danger may exist that they are placed just at that part of the fleet at which the control nets would have caught little or nothing. When only a few trial nets are used, they may be influenced by the control nets on either side of them, so that one cannot decide from their behaviour how a whole fleet of such nets would operate.

As has been mentioned above, a single trial net in a fleet of control nets can, for instance, be held in a suitable position by the action of the neighbouring nets and so make good catches, whereas several trial nets of the same kind might drive together, become entangled, and catch nothing. When large sections of a fleet consist of trial nets, however, the catches may be unevenly distributed over the fleet, and a large number of tests would be required for a precise assessment of their efficiency.

Optimum Efficiency of Herring Drift-Nets.

Before discussing the distribution of the catch in a fleet of herring drift-nets we may consider the maximum quantities that can possibly be caught. The individual nets in the fleet used in the investigation were 800 meshes in length (L) and 360 meshes in depth (T). The total number of meshes (M) is given by the equation:—

$$M = T \cdot L + (T - 1) \cdot (L - 1)$$

A net of the dimensions stated thus has 574,841 meshes. There is, however, no reason to expect that the maximum number of herring caught would equal the number of meshes. The blocking of any one mesh by a fish prevents at least eight other meshes in the vicinity from taking fish, since these meshes become compressed and distorted. The larger the fish is, the more the catching capacity of these meshes will be restricted. Theoretically, then, only 30·8 % — approximately one-third — of the total number of meshes are able to operate. For the net under discussion this implies a catching potential of about 192,000 fish. This will never be attained in practice, however, and experience indicates that 12 "Kantjes" (barrels) per net is the highest yield to be expected. One Kantje is equivalent to between 600 and 800 herrings, depending on size. In the most favourable circumstances the maximum output would then be 9,600 herrings, which implies that only 1·7 % of the meshes are filled. However, such large catches are unusual. The output is considered very satisfactory if a net produces one Kantje, in which case only 0·14 % of the meshes are filled.

According to Kennedy's (1951) studies of gill-nets in the Great Slave Lake, a gill-net's capacity is limited. When "saturation" point is reached, the catch does not increase, even if sufficient fish are present. For this reason it is suggested that more fish would be taken if the nets were shot and hauled more frequently. The possible existence of such a saturation point must be taken into account with the herring drift-nets

also. It would depend on the size of the herring shoals and the size of the individual fish.

General Distribution of the Catch in the Herring Drift-Net.

The statement that even with good catches only a small percentage of the meshes would take fish does not imply that the fish are regularly distributed over the whole net and that each mesh containing a fish is surrounded by a large number of empty meshes. The fish may be concentrated in certain parts either of the single net or of the fleet. There are zones of greater and lower efficiency in each net or in the fleet. Zones of lower efficiency occur near the upper edge near the warp and on each side of the seams between two nets. The inefficient zone along the seams may extend as much as 5 m. from the seam. The nets farthest from the vessel also tend to be inefficient, as is also sometimes the case with those nearest to the ship. On the other hand, the lower edges of the nets and those parts near the "Längen", i.e., the outer edges of the nets at the ends of the "quartels", are relatively efficient.

Quantitative Determination of the Catch taken by the Fleet of Drift-Nets.

The output of one gill-net is characterized by the quantity of fish taken per net, expressed either in numbers of fish or by weight. To count the fish is relatively easy in freshwater and coastal fisheries, where the yield is not too large (v. B r a n d t, 1953 and 1954 a). With large catches or when the nets have to be hauled and the fish removed quickly, as is usually the case in herring drift-net fishing in the North Sea, it is difficult to ascertain the quantity per net. Only small quantities can be counted. Experiments have shown that a reliable enumeration of the herrings taken in a net can only be made when the net does not contain more than 300 fish. With larger quantities of fish the estimates can be considered only as rough.

With large catches the only practicable method of assessing the catch is to take the number of Kantjes over fairly large groups of nets. This is possible aboard the herring luggers (drifters), as after being removed from the net the herrings are put below deck into holds, the capacity of which is measured in Kantjes. From estimates or counts of the number of fish per net, a diagram can be made to illustrate the distribution of the catch in a fleet of drift-nets. In Figures 2—5 the numbers used were rounded off to the nearest 10.[1])

Figure 2 shows the distribution of a small catch of 16 Kantjes in a fleet of 124 nets. The nets were regularly set up in quartels of 10 nets. The catch is very uniform, with about 100 fish per net. There is no definite area of maximum catch either in the centre of the quartels

[1]) The following examples were obtained with (a) a fleet of drift-nets made up of quartels of 10 nets fished by the motor lugger (drifter) "Franz Thiele" of Emden, in July/August 1954 on the West Dogger ground and (b) a fleet with quartels of 20 nets used by the motor lugger "Saxnot", of Glückstadt.

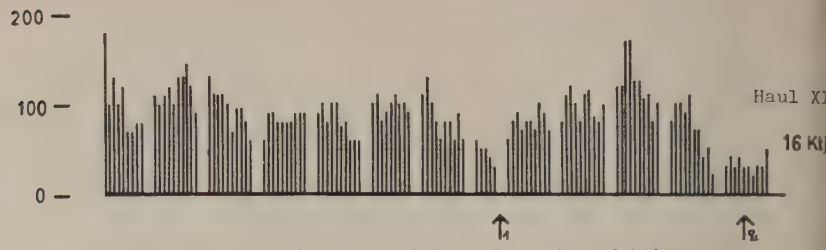

Figure 2. Regular distribution of the catch in a fleet of drift-nets.

or in the nets bordering the "Längen". Although experience leads one to expect larger catches at the ends of the quartels than in the middle, this is correct only in so far as the fish caught are more concentrated at the margins of the nets. The total output of the net differs on the average very little from that of other nets. At the point shown by the arrow (1) the net fouled the warp, and the catch was accordingly small. The last 10 nets (arrow 2) farthest from the vessel were bunched together and therefore fished less well than the other nets in the fleet.

Figure 3 shows a catch consisting of 16 Kantjes only, in which the distribution varies fairly regularly over the fleet. Most fish are in the first half of the fleet, and thereafter the catch gradually diminishes towards the outer end of the fleet. At the point marked by the arrow the net had fouled the warp. The neighbouring nets do not appear to have been affected by this. The decrease of the catch towards the end of the fleet was due to the nets having become bunched together.

Figure 4 shows a catch of 56 Kantjes, most of which is in the nets farthest from the vessel. The catch is not so regularly distributed as in the two preceding examples. This is partly due to a twisted net (marked by an arrow), which caused a break in the middle of an area of high catch covering two quartels.

As mentioned above, a single trial net inserted between conventional

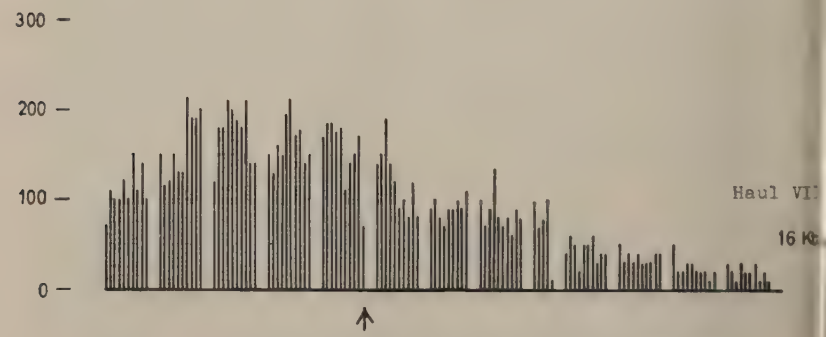

Figure 3. Concentration of the catch within the first half of the fleet.

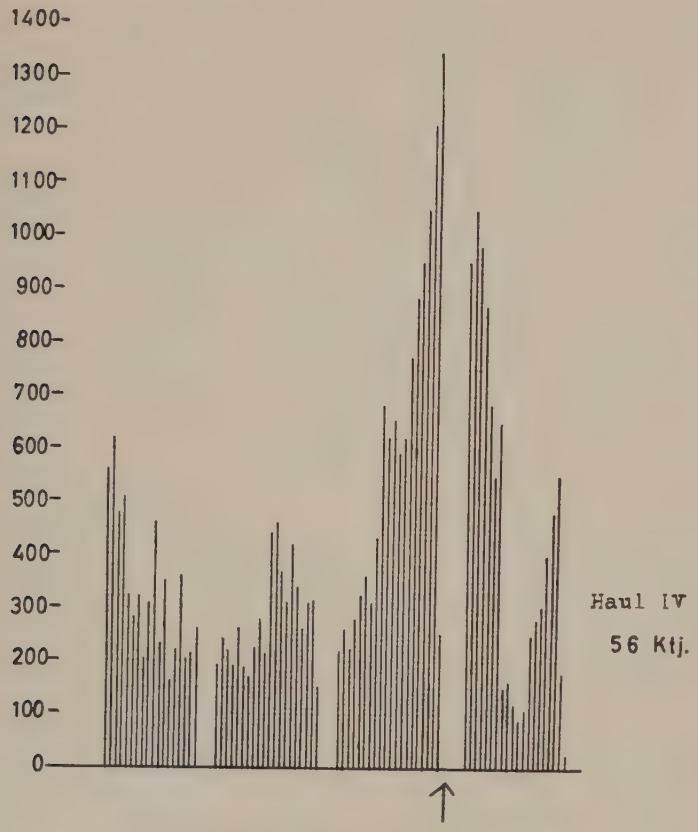

Figure 4. Irregular distribution of the catch.

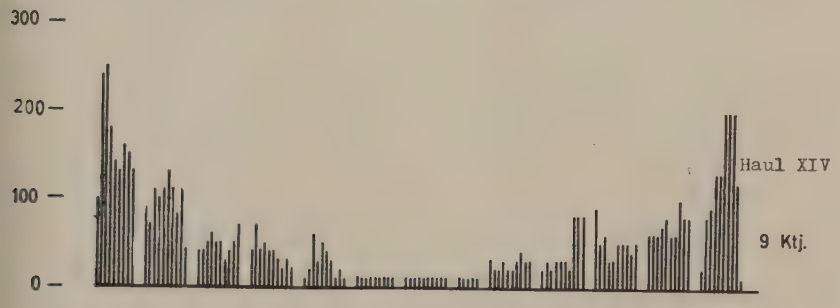

Figure 5. Standard nets disadvantageously influenced by intervening trial nets.

nets can lead to wrong conclusions, because its operation is influenced — and to some extent influences — that of the neighbouring nets. Large sections of unsuitable trial nets affect the fishing of the conventional nets in their vicinity. If the efficiency of these nets is impaired thereby, they no longer provide reliable standards.

In this example (Figure 5) the centrally placed trial nets caught nothing. They tended to ride too high in the water, and as the herring were relatively deep, they floated above the fish. The gradual increase in the catch on either side of these nets leads to the conclusion that the test section drew the neighbouring control nets upwards. This was especially marked in the nets nearest to the trial section.

Summary.

Investigations of the distribution of the catch in a fleet of drift-nets are discussed. These demonstrate that it is a good deal more difficult than was previously believed to assess the efficiency of single trial nets in relation to the other nets of a herring drift-net fleet. Results of a single net are not entirely trustworthy, because the net is affected by the neighbouring nets. Large sections of trial nets, however, may also influence the neighbouring standard nets, and incidental irregularities in the catch of the fleet may lead to faulty estimates of the quantity taken. The best method is to insert fairly large sections of experimental net in a fleet and to repeat the experiments several times. With small catches, the herring taken in each net can be counted, but with large catches the quantities taken per net are better estimated in Kantjes per quartel.

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Winds and Temperatures in Relation to the Brood-Strength of Georges Bank Haddock.[1])

By

Joseph Chase.

Introduction.

The wide year-to-year variation in the brood-strength of haddock has long been of much concern to fisheries investigators on both sides of the Atlantic. Recently, British investigators (Carruthers, 1951) have developed a function of average wind which correlates very well with the brood-strength of North Sea haddock. For Georges Bank, which is situated off the north-east coast of the United States (i.e., on the windward side of the Atlantic), the comparison of brood-strength with average wind has shown only a weak correlation.

The idea of dependence on wind arises from the fact that for some 4 months after spawning begins, the eggs and larvae are normally concentrated in the upper 10 metres of water where they are subject to movement by wind-blown currents. At the end of the pelagic period, the larvae sound, and their survival at the bottom as "zero age" fish depends on their finding bottom at a depth of 150 fathoms or less. The British formula takes cognizance of the mean wind for the pelagic season and therefore of the position of the larvae relative to shoal water at the end of the season. Brood-strength has been shown (Parrish, 1950) to be largely independent of events occurring outside the pelagic season.

The hydrography of Georges Bank and adjacent waters suggests the necessity of examining daily winds in order to reach a better correlation for that area. The easterly current, which lies just off the shelf (Bigelow, 1924, pp. 936—942) at a distance of some 50—75 miles south-south-east of the middle of the bank, provides the possibility of loss of eggs and larvae after a régime of north-westerly winds, regardless of a later régime of south-easterlies. There is an indication of this type

[1]) Contribution No. 735 from the Woods Hole Oceanographic Institution.

of action in drift-bottle records. Another possible source of loss is found in the much higher temperatures which exist off the shelf.

This situation is in contrast to that of the North Sea, where currents flow in a general counter-clockwise circulation, so that average wind more nearly indicates the net travel of eggs and larvae, and where the temperature gradients are smaller.

Brood-Strength.

The data on Georges Bank haddock brood-strength were furnished by the Fish and Wildlife Service of the U. S. Department of the Interior. They include final figures for the year-classes of 1928 to 1949 and

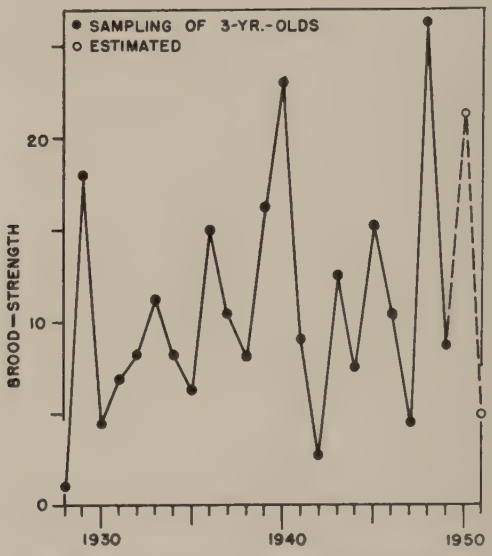

Figure 1. Brood-strength of Georges Bank haddock.

estimates for 1950 and 1951 (Figure 1). The year-class strength is determined at Boston, Massachusetts, by a careful sampling count of 3-year-old fish from the catches of commercial fishermen and is believed to be accurate to within one unit. Ten units on the scale represents a normal brood-strength and the range is from 1 (1928) to 26·3 (1948) units.

Wind.

The wind values are expressed in terms of daily (1230 GMT) pressure difference between Nantucket, Massachusetts, and Yarmouth, Nova Scotia. This pressure difference is proportional to the component of geostrophic wind normal to the Nantucket—Yarmouth line. It corresponds to the component of wind-driven current normal to the southern edge of Georges Bank if wind-driven currents in this region

move at an angle of 25° to the right (clockwise) of the geostrophic wind. This angle is reasonable if it can be assumed that surface wind direction is about 20° to the left of the geostrophic wind and that surface water is driven in a direction 45° to the right of the surface wind.

The study is confined to the offshore components on the assumption that very little, if any, loss of eggs and larvae results from wind and current in other directions. According to their lengths and strengths, the principal régimes of offshore components are presumed to carry off eggs and larvae in varying amounts, i.e., to do varying amounts of "damage" to the potential brood-strength. The greater the total of damage during the pelagic season, the smaller the brood-strength should be.

Damage Assessment.

"Damage units" were assigned to the principal offshore régimes according to an empirical table. This table (Table 1) lists increasing numbers of damage units according to the number of days for which the Nantucket—Yarmouth pressure difference was continuously 5 mb. or more, and extra units for the number of days of continuous pressure difference of 10 mb. or more.

Table 1.

Days of continuous pressure difference	Damage units for régime
of 5 mb. or more	
1	1
2	2
3	4
4	7
5	10
6	13
7	16
of 10 mb. or more	
1	1
2	3
3	5

The form of the table and the non-linearity of the early part of the damage-units column was suggested by an inspection of daily winds for a few pelagic seasons. The empirical damage-unit scale is the result of trial-and-error fitting to the pressure-difference data and brood-strength data for the years 1928—1931.

A 5 mb. difference corresponds to a surface wind of about 20 m.p.h. At a ratio of current in knots to wind in m.p.h. of 0·035, this gives a water movement of about 17 nautical miles per day, which is enough to transport eggs and larvae from the normal edge of the pelagic field at the 50 fathom curve to the easterly current. This ratio is a little

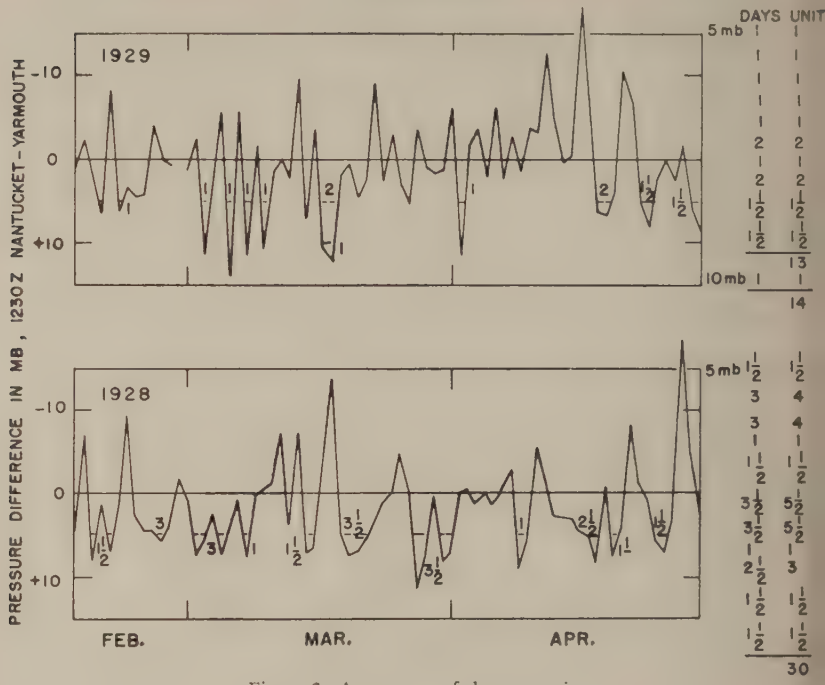

Figure 2. Assessment of damage units.

higher than most of those found by H a i g h t (1942, p. 70) in a study of coastal lightship data but seems reasonable in view of the offshore position of Georges Bank. The proportionally greater damage-unit figures listed for the longer régimes are to account for the denser distribution near the centre of the pelagic field and for the greater water speeds probably attained after the first two or three days.

In assessing the length of the régimes, some allowance was made for the rate of change of pressure differences near and during each régime. Variations due to subjectivity in the counting of damage units probably do not exceed two units for any season.

The normal pelagic season is from 17. February to 15. June. The period from 2. May to 15. June has been left out of the damage-unit calculations because of its generally light winds and small year-to-year variation in damage count.

Examples of damage count are shown in Figure 2.

Fixed Date Correlogram.

When damage counts for the period 17. February—1. May for each of the 24 years were compared with the corresponding brood-strength figures on a correlogram, some correlation was apparent, seventeen of

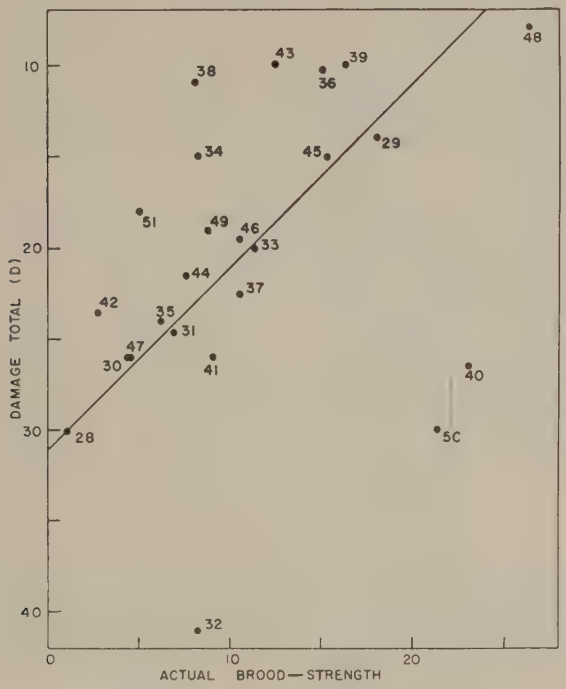

Figure 3. Fixed date correlogram.

the points lying within 6 units of a straight line (Figure 3). The other seven points probably reflect the influence of other variables such as are often present in biological problems. Some other danger to haddock than wind may have reduced the brood-strength for the years 1934, 1938, 1943, and 1951. More of a problem are the cases of 1932, 1940, and 1950, where the brood-strength was higher than the damage totals indicate.

A factor which might account for deviations on either side of the line is variation in the spawning time. Variations of this nature are often associated with temperature and it is interesting that in 6 of the 7 years showing large deviations, there were anomalous air temperatures at New England coastal stations. There are indications that spawning time does vary but the details of this variation are unknown at present. Though any attempt to introduce temperature into the formula at this time must be somewhat arbitrary, it nevertheless seems warranted in view of the anomalous temperatures.

Temperature Sequence.

Perhaps the best available data for indicating the water temperature

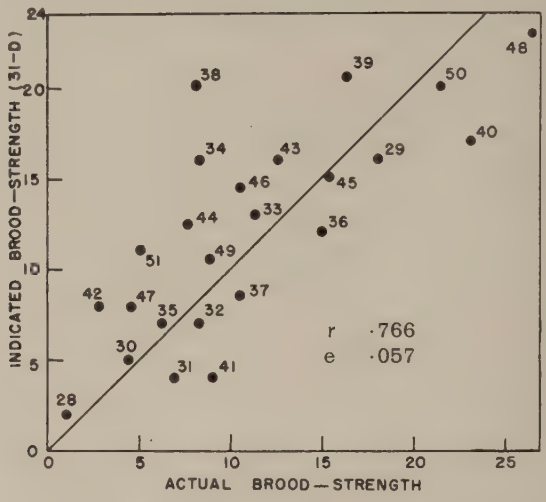

Figure 4. Variable date correlogram.

of Georges Bank are the 5-day means of surface water temperature at "Nantucket Shoals" lightship, the available file of which covers the 16 years 1928—1932, 1934—1941, 1948, 1949, and 1951. These temperatures may be more influenced by short-period weather than are those of the bank but it is believed that the difference in influence is small.

These data show that on the average a definite lessening of the rate of cooling occurs at about normal spawning time, i.e., 17. February, the drop in temperature for the period from 16. February to the minimum on 6. March being about $^1/_3$ that of a like period ending on 16. February. This time of the change of rate on the individual years was taken as the starting date for damage count. The date varied between 1. February and 21. March.

Due to oscillations resulting from short-period weather, this change was sometimes not well marked. However, in a majority of cases it was well marked and occurred at a temperature 1·5°F. above that of the minimum. To make the selection as objective as possible, the count was started when the temperature last fell to within 1·5°F. of the eventual minimum.

To handle the eight cases not covered by the "Nantucket Shoals" data, the monthly mean air temperatures (U. S. W. B.) for Nantucket, Massachusetts, and Eastport, Maine, were used. The normal time of the minimum of the mean temperature between the two stations is about 30. January, which is 18 days before the normal beginning of spawning. The starting date for damage count was therefore set, for each of the years, at a date 18 days after the date (interpolated) of the minimum air temperature.

Variable Date Correlogram.

The application of temperature to the formula resulted in the correlogram of Figure 4. For the ordinate of the figure, the seasonal damage (D) has been replaced by the indicated brood-strength (31-D). The correlation coefficient between indicated and actual brood-strengths is $0{\cdot}766 \pm 0{\cdot}057$, which is well above 0·515, the 1% level of significance for 24 cases.

The principal improvement is in the reduction of the deviations for 1932, 1940, and 1950, which years had late temperature minima. Also improved are the points for 1943 and 1951. The points for 1934 and 1938 remain unchanged. February of 1934 had the lowest water and air temperatures of all of the period examined, while 1938 had a very normal winter. The hurricanes of 1938 and 1944 may have reduced the brood-strengths of those years.

The relative merits of air and water temperatures for use in the formula were tested by calculating indicated strengths with air temperatures for the 16 years already treated with water temperatures. The water temperatures led to better results in 7 cases, poorer results in 2 cases, and equal results in 7 cases.

Acknowledgements.

The writer wishes to thank Dr. C. O'D. Iselin and Mr. F. C. Fuglister, of the Woods Hole Oceanographic Institution, for their interest and guidance in this study, and Mr. G. G. Pasley, Jr., for the drafting of the figures.

Summary and Conclusions.

1. An empirical formula for predicting the brood-strength of Georges Bank haddock is presented. The formula makes use of the wind during the pelagic season and of the winter water or air temperatures. While the formula works well for the 24 years of available brood-strength data, the need for more research on haddock and their environment is apparent.

2. A correlation of $0{\cdot}766 \pm 0{\cdot}057$ has been found between the actual brood-strength of Georges Bank haddock and an indicated brood-strength. This indicated brood-strength is a function of offshore wind during a part of the pelagic season beginning with a date determined by temperature sequence and ending on 1. May.

3. At the present time there is insufficient knowledge of the variations in the spawning time of Georges Bank haddock and their possible connexion with environmental temperatures to establish a firm ecological basis for the formula for indicated brood-strength. Intensive study of spawning and the establishment of a programme of water temperature observations appear to be in order for purely scientific reasons as well as for the practical importance which the forecasting of brood-strengths has in the conservation of a commercially valuable fish.

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Swedish Investigations on Plaice and Flounder in the Southern Baltic.

By

Arvid R. Molander.

I. Plaice.

Landings of Plaice.

The total Swedish landings of plaice from the south coast of Sweden during the period 1921—52, inclusive, according to the available Swedish statistics (Sweden's Official Fishery Statistics), are shown in Figure 1. The diagram also shows the catches landed during the same period by fishermen from Kristianstad län and from Blekinge län (see the chart). The catches landed by fishermen from Bohuslän are also given for the period 1922—26; these fishermen, encouraged by the favourable results of the Swedish fishery investigations, were the first to start a profitable fishery with the Danish seine in the southern Baltic. The total Swedish landings from the south coast also include catches from Malmöhus län, but these are not shown separately in the official statistics except for trawl-caught fish.

Figure 1 furnishes a general idea of the development of the plaice fishery from the time when modern gear (the Danish seine and especially the trawl) first enabled the fishing grounds in the southern Baltic to be exploited in a more rational manner up to the early 1950's. The most striking development in this connexion is perhaps that exhibited by the fishery in Kristanstad län and Blekinge län.

The expanding plaice fishery reached its peak in the early 1920's. Thereafter a decline set in, which continued during the latter part of the 1930's, despite the introduction in 1931 of international measures for the protection of fish stocks; these prohibited the fishing of plaice in February and March. The purpose of these measures was to protect the plaice during the spawning season and thus facilitate recruitment to, and preservation of, the stock. The effect of the actual fishery was, however, not reduced; the savings made during the two close months of February and March increased the landings in the months immediately

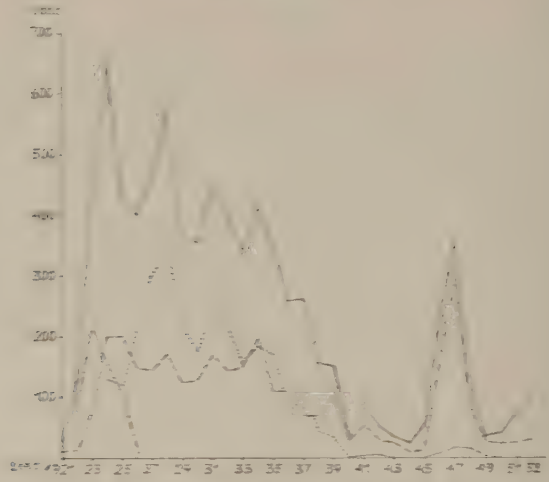

Figure 1. Total Swedish landings of plaice from the southern Baltic, 1921—1952 ————
Landings by fishermen from Kristianstad län - - - - - -
. Blekinge .
. Bornholm . - - - -

Chart showing the localities to which the present study refers.

Table 1. The percentage proportion of the annual takings for the 1st and 2nd quarters of the years 1928 and 1930 and of the years 1932 and 1934 (Sweden's Official Fishery Statistics).

Year	1st Quarter	2nd Quarter	Total
1928	32·2	31·0	63·2
1930	30·3	21·9	52·2
1932	12·1	37·9	50·0
1934	7·7	42·8	50·5

following. It will be seen from Table 1, which shows the percentage proportion of the annual landings for the first and second quarters of the years before and after 1931, that the percentage proportion of the yield for the second quarter of the years after 1931 rose so much that the increase almost entirely balanced the reduction in the proportion for the first quarter; this reduction was inevitable owing to the introduction of the protective measures. The savings effected in the first quarter were soon used up.

The advantage of protecting the plaice during the spawning season is also to some extent eliminated by the fact that the production of new year-classes has proved so extremely irregular, owing to fluctuations in natural conditions.

During the war the fishery consistently deteriorated and became less and less valuable. This happened concurrently with a marked increase of the fishing fleet (with the exception of 1940; see Table 2), although the vessels were employed in other fisheries, primarily in the rapidly developing cod fishery and later in herring trawling. The plaice fishery fell into obscurity. With the poor supply of plaice, other fisheries were more profitable. But in the years immediately after the war, 1946—47, the landings showed a considerable increase; this was most probably due to the stock having accumulated during the war years when the plaice fishery was less intense. But by 1948 and 1949 a steep fall in yield was again noticeable. In 1951 and 1952, however, there was a further slight rise, although the value of the catches did not exceed those of the landings during the war years. During the most recent years (1951—52) the rise in the number of vessels engaged in the Baltic fishery has been further accentuated, concurrently with an expansion of the trawl fisheries for cod and herring. The expansion of the plaice fishery during these years is probably to be ascribed therefore to a temporarily

Table 2. The number of fishing vessels from Blekinge, Kristianstad, and Malmöhus län engaged in trawling in the southern Baltic in the period 1936—52 (Sweden's Official Fishery Statistics).

Year	Vessels	Year	Vessels	Year	Vessels	Year	Vessels
1936	60	1941	67	1945	88	1949	161
1937	62	1942	68	1946	107	1950	157
1938	66	1943	94	1947	107	1951	174
1939	65	1944	89	1948	125	1952	172
1940	64						

improvement of the stock, due to slightly better representation of certain year-classes. The variations observed in the total quantities landed from year to year (Figure 1) are evidently connected also with the appearance of year-classes of unequal strength. Now that the large surpluses from former years have disappeared, annual recruitment to the stock will probably tend to maintain it at about the present level, though fluctuations in the fishery must inevitably result. However, these variable additions to the stock are incapable of producing very great increases in the catches or of compensating entirely for the takings of the fishery.

The plaice fishery in Kristianstad län and Blekinge län completes the picture of the general development of the fishery in the southern Baltic. In Kristianstad län the modern fishery started relatively early (1923—24) and remained fairly uniform until the sharp fall in the mid-1930's. The much improved fishing in 1946—47 was very striking in this district also. The Blekinge fishery had a period of very great prosperity at the end of the 1920's, but after that time a fairly general

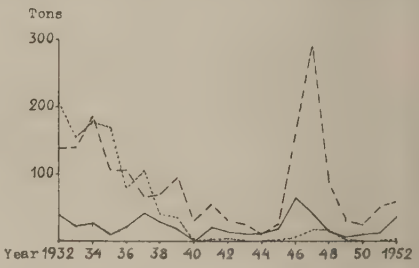

Figure 2. Landings of trawl-caught plaice from the southern Baltic, 1932—1952.
Landings by fishermen from
Malmöhus län _____
Kristianstad „ - - - - - -
Blekinge „ .....

decline set in which lasted until the war. During the war the Blekinge plaice fishery was quite insignificant, and no improvement in the size of the catches occurred during the following years. Thus, in the region frequented by the Blekinge fishermen, the deterioration in the fishery has been much more marked. The depletion of the plaice stock seems therefore to be more pronounced in the eastern and more marginal parts of the region in which the plaice is distributed. The picture which Figure 2 gives of the fishery in the southern Baltic is in entire agreement with that in Figure 1. The trawl-caught landings are shown from 1932 and onwards. The returns for Malmöhus län probably relate to the catches made by fishermen from this län in the southern Baltic. As may be seen, the trawl catches from the other districts constitute the major part of the plaice fishery.

No very detailed investigations of the stock of flatfish in the southern Baltic have been undertaken in Sweden in recent years. Some trawling has been carried out by the "Skagerak" (1948—49) and the "Eystrasalt" (1946—47). The "Eystrasalt" hauls were made in the Bornholm area, mostly 12—14 nautical miles E.S.E. from Simrishamn. This also applies to the "Skagerak" hauls, but the catches landed by this vessel also include plaice from the locality south of Ystad.

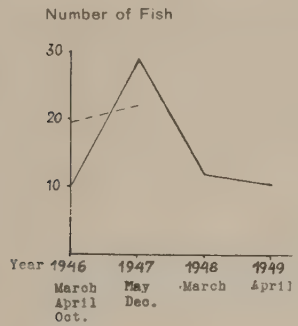

Figure 3. Average catch of plaice per one-hour haul, from investigations by the "Skagerak" and the "Eystrasalt" in the southern Baltic, 1946-1949.
Catches March—May ————
" Oct.—Dec. - - - - - -

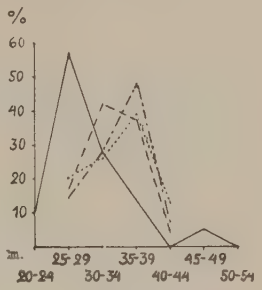

Figure 4. Percentage distribution of length-groups of plaice, from investigations by the "Skagerak" and the "Eystrasalt" in spring (March—May);
1946 ——— 1947 - - - - - -
1948 · - · - 1949 · · · · · · ·

The catches were usually small (Figure 3) and are included merely to supplement the values shown in Figures 1 and 2. The catches in question were made with the ordinary type of trawl, with the usual size of mesh. Although the landings recorded are small and scarcely provide a completely reliable idea of the strength of the stock and the prospects of the fishery, they are nevertheless in clear agreement with the variations in the total landings as demonstrated by Figures 1 and 2. Figure 3 shows the average catches per one-hour haul in 1946—49 (March—May, October—December). It will be seen that the catches were relatively large in 1946—47 and that they undoubtedly declined in 1948—49.

Length- and Age-Groups.

Figure 4 shows the percentage distribution of the length-groups for plaice obtained from the "Skagerak's" and the "Eystrasalt's" hauls in spring (March—May) over the period 1946—49. For clarity, the length-groups are arranged in 5-centimetre groups. The coarse mesh of the trawl used allowed most of the small plaice to escape.

It will be seen from Figure 4 that in 1946 the lower length-groups of plaice, between 25 and 29 cm., were preponderant. In 1947 a displacement occurred in favour of slightly larger plaice, principally between 30 and 34 cm., but also between 35 and 39 cm. In 1949 the composition of the stock remained much the same, although plaice between 40 and 45 cm. were rather more numerous.

Except in 1946, when the stock included a comparatively large number of small plaice (25—29 cm.), the higher length-groups dominated during the period concerned. With this single exception, no substantial supply of small plaice seems to have been forthcoming during these years.

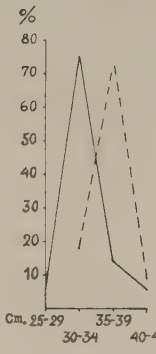

Figure 5.

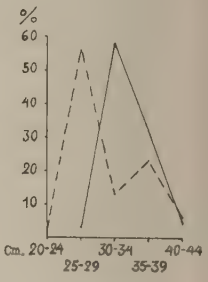

Figure 6.

Figure 5. Percentage distribution of length-groups of plaice, from investigations by the "Eystrasalt", Oct. 1946 ———— Dec. 1947 - - - - - - -

Figure 6. Percentage distribution of length-groups of plaice landed by fishing vessels from the southern Baltic. May 1948 ———— April 1951 - - - - - -

Figure 5 shows the size distribution of the plaice in the "Eystrasalt's" catches in October 1946 and December 1947. In the autumn of 1946, after the summer period of growth, the 30—34 cm. length-group was preponderant and plaice between 35 and 39 cm. predominated in December 1947. Thus, the autumn catches show that a distinct displacement of the composition took place from 1946 to 1947 in favour of larger plaice.

In Figure 6 curves are given, for comparison, of the size distribution of plaice landed by fishing boats in 1948 and 1951. The catch in May, obtained from a more easterly position (E.S.E. of Christiansø) than the catches of the "Skagerak", shows a slightly stronger 30—34 cm. length-group than does the "Skagerak" catch from March of the same year. In 1951, on the other hand, there was a strong influx of small plaice (25—29 cm.), which appreciably outnumbered the larger plaice and altered the character of the stock.

On the whole it may be said that during the period concerned the stock of plaice was usually dominated by large individuals and that the influx of smaller plaice seems to have been significant only in 1946 and 1951.

Turning now to the distribution of the year-classes in the trawl catches for the period, 1946—49, we find (Figure 7) that age-groups III and IV were the most prominent, with group IV definitely in the lead. The year 1946 is an exception, however, for then group III (the 1943 year-class) was very strongly represented. It was strongly marked even as group IV in 1947 and as group V it formed a not inconsiderable part of the stock. Otherwise group III occurred fairly uniformly during the period 1946—49 without being outstanding, which suggests, as did the length-group distribution, that the addition of new year-classes was not a marked feature of these years. The marked increase in the catches in 1946 and 1947 is probably connected in the first place with the emergence of the 1943 year-class as groups III and IV respectively. The distributions of the year- and length-classes thus present similar pictures of the stock.

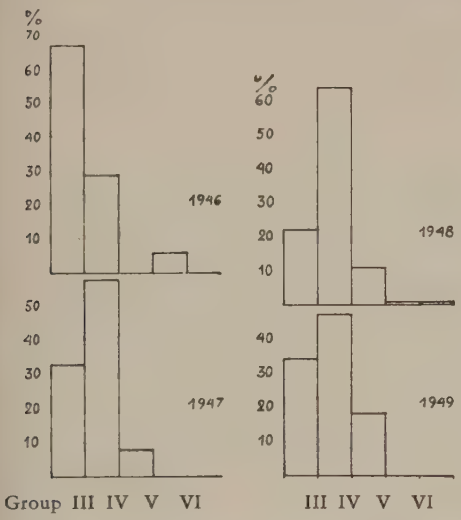

Figure 7. Percentage distribution of the age-groups in the catches of plaice in March—May 1946—1949 (cf. Figure 4).

An age-distribution analysis of the sample of plaice obtained from a fishing vessel in April 1951 revealed only age-groups III to V. Group III, however, was very strong; this seems to be the year-class which contributed most to the rise observed in the catches in 1951 (Figure 8).

An analysis was made of a sample of plaice taken N.E. of Bornholm by a Simrishamn fisherman in May 1943, when the plaice fishery in the southern Baltic was insignificant. Age-groups III—VII were represented, group III quite sparsely, but the older plaice, especially groups IV and V, relatively abundantly. The age distribution gives the impression of a fairly old stock, similar to that observed for 1947—49. Nevertheless it is clear from the age-groups present in 1943 that none of the year-classes from the period immediately before the war had been very

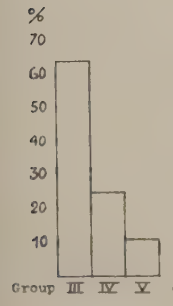

Figure 8.

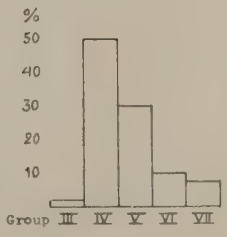

Figure 9.

Figure 8. Percentage distribution of age-groups in catches of plaice from a fishing vessel in April 1951.

Figure 9. Percentage distribution of age-groups of plaice in catches from a fishing vessel in May 1943.

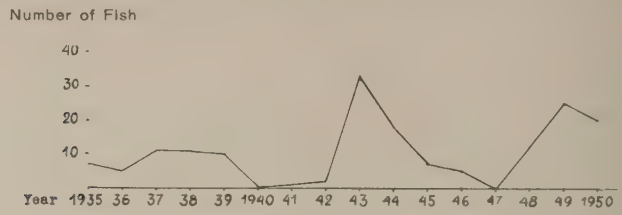

Figure 10. Average catches of 0-group plaice in the Bornholm coastal region. Number per 30 minutes' fishing with the hand push net (Danish investigations).

strong. Even though groups IV and V were well represented proportionately, they were evidently insufficient to increase the yield of the fishery appreciably.

The various samples examined show clearly how limited was the number of year-classes comprised in the catches. Age-groups III and IV mainly predominated. Group V was considerably less numerous than groups III and IV, and older plaice occurred very rarely. This suggests that the drain on the stock was severe. The relatively better representation of groups V—VII in the stock, as was the case in 1943, for instance, may indicate that the fishery was not so intensive as to prevent the accumulation of some surplus of older and larger plaice.

It is of interest to compare the relationship between the various year-classes present in the stock in different years with the occurrence of the 0-group in the coastal regions of the southern Baltic. Data on the 0-group are available from both Danish and Swedish investigations. Fishing experiments covering the coasts of Bornholm have been carried on for many years by Denmark, and Sweden has made similar observations on the occurrence of the 0-group off the south and east coasts of Scania. The Swedish investigations were suspended during the war.

Figure 10 gives the average catches of 0-group fish per 30 minute haul off Bornholm for the years 1935—50, according to the Danish investigations (Ann. Biol., **2**—**6**). Fishing was carried out with the hand push net. It may be seen that group 0 occurred comparatively uniformly, though not to any especially pronounced extent during the pre-war years. But in 1943, on the contrary, the catch of 0-group plaice was very large. Quite good 0-groups occur again in both 1948 and 1949, at the end of the decade. The Swedish investigations (Figure 11) in

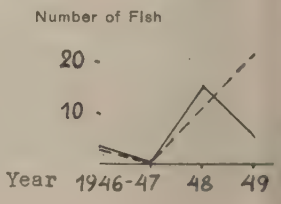

Figure 11. Average catches of 0-group plaice in the Scania coastal region. Number per 30 minutes' fishing with the Johansen trawl (Swedish investigations).
South coast of Scania ———
East coast of Scania - - - - - -

the years 1946—49 off the south and east coasts of Scania were made with the Johansen trawl. They also reveal abundant 0-groups in 1948 and 1949. Group 0 occurred in greatest numbers off the south coast in 1948 and off the east coast in 1949 (Ann. Biol., **3—6**).

If the occurrence of the 0-group is compared with the distribution of the different year-classes in the plaice stock, as shown in Figures 7—9, it will be seen that the abundant 0-group of 1943 is reflected in the catches in the years 1946—49. As already mentioned, in 1946 group III, and in 1947 group IV, were most prominent. The 1951 catches also included a strong III-group. In this case it is obviously the rich 0-group of 1948 which is in evidence. The improvement in the yield in 1952 may also be associated with the contribution to the stock deriving from the fairly good 0-group of 1949. The comparatively uniform, though not particularly abundant, occurrence of 0-groups in pre-war years (1937—39) may also have influenced the composition of the stock in 1943. This confirms the statement made above to the effect that the contributions of the relatively strong year-classes are mainly responsible for the improvements in the stocks as shown by the increased landings.

Age and Growth of the Plaice.

The material available for determinations of age and growth is regrettably scanty (Table 3), but from those that have been made it is clear that the plaice in the southern Baltic are now growing very strongly (Figure 12) as compared with the position in the early years of the fishery[1]).

Table 3. The average length of plaice by age-groups, in samples from 1943, 1946—49, and 1951.

Year	Sex	Age-Groups III	IV	V	VI	VII
1943	♂	—	32·4(15)	34·2(5)	40·0(1)	37·0(1)
	♀	34·0(1)	38·4(4)	39·1(12)	44·6(4)	42·5(3)
1946	♂	26·4(12)	32·0(5)	—	—	—
	♀	26·5(2)	32·1(1)	—	46·0(1)	—
1947	♂	26·2(4)	30·6(3)	—	—	—
	♀	—	33·5(15)	39·5(2)	—	—
1948	♂	28·3(14)	34·4(17)	34·4(4)	—	—
	♀	31·5(2)	36·3(30)	38·0(4)	45·0(1)	52·0(1)
1949	♂	28·7(21)	35·0(25)	37·0(2)	—	—
	♀	32·2(5)	38·5(11)	41·0(8)	—	—
1951	♂	27·1(24)	31·0(3)	38·0(2)	—	—
	♀	28·3(10)	36·1(10)	39·2(4)	—	—

This vigorous growth is concomittant with the heavy thinning of the stock which has taken place since the fishing was intensified, and the

[1]) A. R. Molander: Sv. Hydrogr. Biol. Komm. Skr., N. S., Biologi, **1**, 1—2, 1925, 1926.

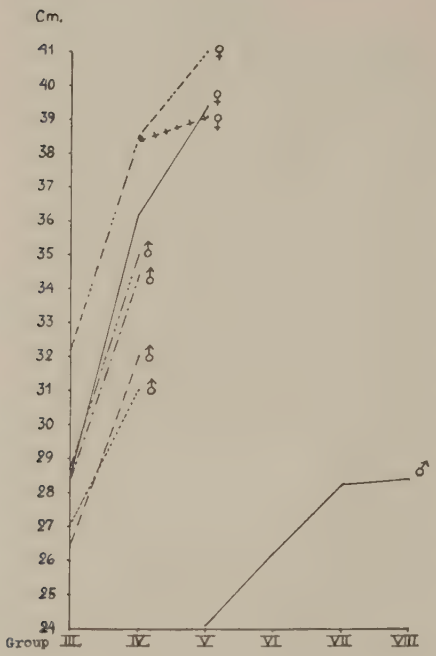

Figure 12. Average length of age-groups of plaice from the southern Baltic.
♂ May 1927 ——— ♀ May 1943 +++++
April 1946 - - - - April1949· · · · · ·
March 1948 - · - · April 1951 ———
April 1949 - · - · -
April 1951 · · · · ·

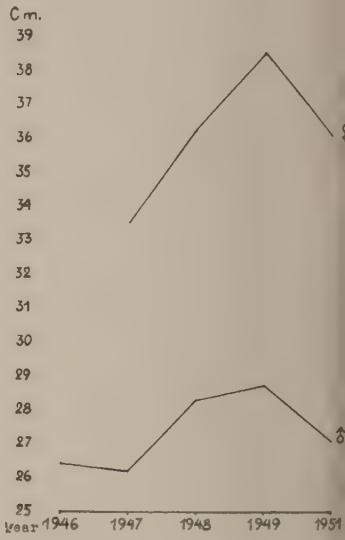

Figure 13. Average length of III-group (males) and IV-group (females) plaice in the catches in the years 1946—49 and 1951.

rapid growth is still very noticeable. Certain differences can be observed, however, in the growth of various year-classes which show that growth is affected by variations in the density of the stock. Thus, for instance, (Figure 13) the females belonging to the IV-group in 1947 show a lower average length than the corresponding groups in 1948 and 1949. Furthermore, groups III and IV likewise have lower average lengths in 1951 than in 1948 and 1949. Thus, the fluctuations in the growth of the plaice also indicate to some extent the variations in the density and strength of the stock.

As a rule males exhibit a lower average length than females in the same age-group. The growth of females is thus more rapid than that of males and they are more numerous in the older year-classes.

Conclusions.

In the 1920's and 1930's the fishery in the southern Baltic led to severe depletion of the stock of plaice. This drain continues, and the stock at present can only accomodate a comparatively insignificant fishery. The stock of marketable fish is maintained chiefly by annual recruitment. As this is very irregular in amount, there are considerable fluctuations in the stock and in the yield of the fishery.

As far as the fishery is concerned, the thinning out of the stock is certainly counteracted to some extent, over and above the contribution made by relatively strong year-classes, by the extremely rapid growth of the plaice which still persists. This helps to intensify the effect of a strong year-class. Nevertheless the supply available seems inadequate to meet the requirements of the fishery. The supply still largely depends on the development of the year-classes. The Swedish fishermen appear to have appreciated the practical implications of this state of affairs and realize that it does not pay to carry on the plaice fishery beyond a certain point. As soon as an improvement in the supply of plaice becomes apparent, the fishermen again increase their activities, to the extent to which it is profitable to do so. In other words, the fishery becomes adjusted to the supply. The fact remains, however, that once the surplus has been taken, the stock is left with little opportunity to recover, since the most favourable pre-requisites for uniform annual recruitment no longer exist. In these circumstances, the question may well be asked whether there is any possibility of a substantial recruitment being made to the stock of plaice in the southern Baltic without resorting to measures for complete protection over long periods. A short close season of a few months in each year has not produced the desired effect. An increase of the minimum size, to 26 cm., for instance, would be of little use, as the number of plaice up to this length form a very small minority in the trawlers' catches on the most important fishing grounds in the southern Baltic.

II. Flounder.

Landings of Flounder.

Figure 14 shows the total Swedish landings of flounder from the southern Baltic in the years 1930—52. In the Swedish returns (Sweden's Official Fishery Statistics), however, "flounder" includes both flounder and common dab. A distinction has been made between these two species in some years only. To give a clearer picture of the catches of flounder and the fluctuations during the period concerned curves are given in Figure 14 which show the quantities of trawl-caught flounder for Kristianstad län and Blekinge län combined. The records for these regions also do not always distinguish between flounder and common dab, but for the years in which the species were not separately recorded, it has been possible to estimate, from samples for other years, the proportion of the two species in the catches. The curve given thus includes estimated landings of flounder. The Danish landings of flounder in the southern Baltic are also shown in Figure 14; these data are taken

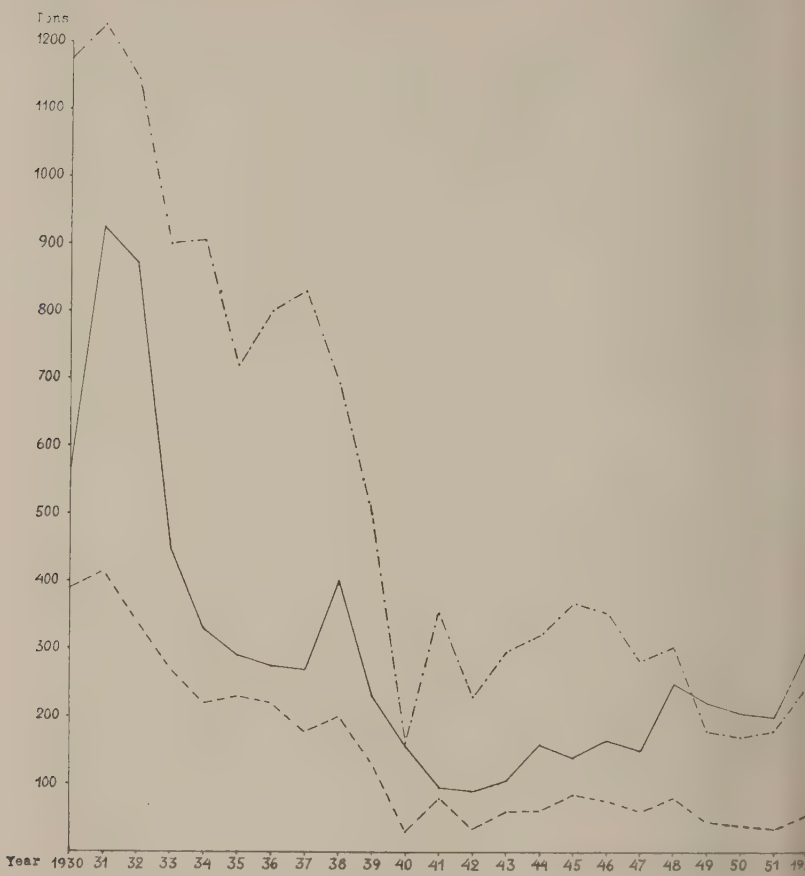

Figure 14. Landings of flounder from the southern Baltic, 1930—1952.
Danish ————
Swedish (flounder and common dab) - - - - - - - -
Trawl-caught flounder landed by fishermen from Kristianstad and Blekinge län - - - - - - - - -

from Denmark's Official Fishery Statistics (*Dansk Fiskeri-Beretning*) for 1930—1952.

The landings of flounder from Blekinge län and Scania län for 1925—1930 have been published previously (M o l a n d e r, Rapp. et Proc.-Verb., **78**, 1932). The abundant catches recorded during the late 1920's continued into the opening years of the 1930's (op.cit., Figure 1), but in the closing years of that decade a very pronounced decrease in the quantities landed set in, which continued until the outbreak of war. During and

after the war the flounder fishery remained at a comparatively low level. Though the yield remained fairly uniform, annual variations occurred. For instance, there was a distinct increase in the landings in 1948 and 1952, and in the latter years of the war and immediately after, according to the Danish records at least, some increase in the landings occurred, as has been noted in the case of the plaice landings also. The comparatively uniform yield of the fishery in recent years is indicative of a more stable stock, from which the earlier surpluses have evidently disappeared and in which the fluctuations of the catches reflect the variations in year-class strength. The fishery is now maintained by annual recruitment to the stock, and the strong year-classes produce a relatively great effect. The number of fishing vessels engaged in the Swedish fishery in the southern Baltic rose considerably after the war (cf. Table 2, p. 27), but these were mainly engaged in fisheries other

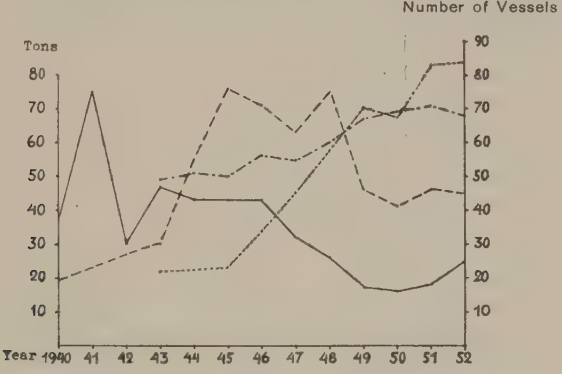

Figure 15. Landings of flounder, 1940—52, by fishermen from Kristianstad (———) and Blekinge län (- - - - -). Number of fishing vessels Kristianstad län - · - · - · - · - · Number of fishing vessels Blekinge län · · · · · · · · · ·

than for flounder. The slight improvement in the flounder fishery after the war was thus probably due, not to the intensification of the fishery, but to a better supply of flounder resulting from comparatively good year-classes.

Figure 15 shows the catches of flounder in 1940—52 from Blekinge län and Kristianstad län, as estimated from the ratio of flounder to common dab in the total landings of "flounder" recorded in the Swedish returns. It may be seen that the catch of flounder from Blekinge län is much larger than that from Kristianstad län; this is in contrast to the position with plaice. Figure 15 also gives the number of fishing vessels in the two districts in the years 1943—52. As may be seen, this number rose sharply in later years but there was no corresponding increase in landings.

The improvement in the fishery from Blekinge län suggests that a

better stock of flounder is now present on the grounds frequented by the Blekinge fishermen. These grounds are usually further to the east (S.E. of Hanö and Utklippan, and S. and S.E. of Christiansø) than those of the fishermen from Kristianstad län. There the flounder lives under much more favourable conditions than the plaice, with the result that its power of resistance to the fishery has increased. On the whole one may say that the flounder in the southern Baltic enjoys much more favourable living conditions than the plaice, so that the prospects of maintaining the stock at its present level — greatly reduced though this is in comparison with its size when the Danish seine and trawl were first used — seem comparatively good. The fishery adapts itself to the existing supply of fish and to the profit that can be made.

Length- and Age-Groups.

Figure 16 illustrates the percentage distribution of the length-groups of the flounder in the trawl hauls made by the "Skagerak" (1927, 1930,

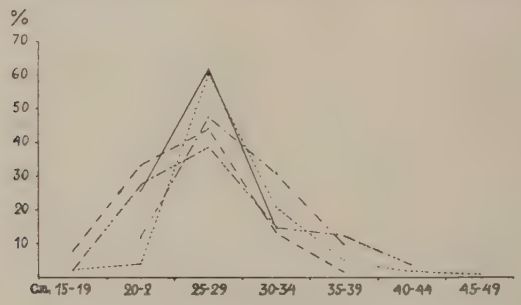

Figure 16. Percentage distribution of length-groups of flounder from the southern Baltic.
May 1927 ———— April 1949 - · · - · · -
Febr. 1930 - - - - - - - - - May 1954 · · · · · · · · · ·
March 1938 - · - · - · - · -

1938, and 1949) and by a Blekinge fishing vessel (1954). All the catches were made in spring (February—May); the mesh of the trawl used was normal for this type of trawl. The length-groups are shown for 5-cm. intervals. Owing to the selective action of the trawl, very few small flounder were landed.

A comparison between the stocks present in various years shows that the 25—29 cm. length-group always predominated. In 1927 there were only a few fish of the next highest length-group, and fish of still larger size did not occur at all. By 1930, however, some large fish of the 35—39 cm. group had begun to appear. The increase in the numbers of larger individuals was pronounced in 1938, and still more so in both 1949 and 1954. The 1954 catches include flounder even of the 45—49 cm. length-group (2 fish of 46 cm. and 1 of 48 cm.). The increase in the demands on the stock has thus led to a very definite rise in the

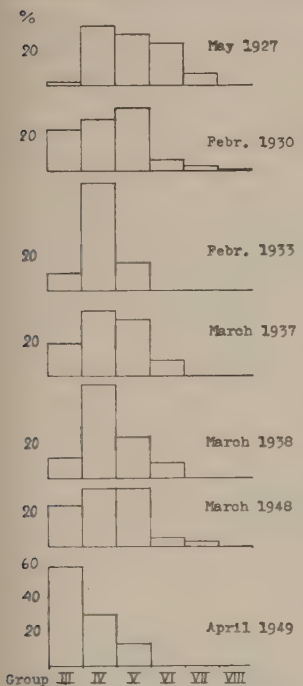

Figure 17. Percentage distribution of age-groups of flounder from the southern Baltic, 1927—1949.

numbers of large flounder. The fact that the 25—29 cm. length-group still predominates, despite the increase in the number of larger fish, may appear to imply that annual additions to the stock are relatively uniform. But with the change in the growth of the flounder associated with the depletion of the stock and the increase in the numbers of the larger fish, the presence of large numbers in the 25—29 cm. group does not mean that a certain year-class necessarily predominates. This is primarily due to the fact that this length-group is the limit at which the smaller fish are taken by the trawl, and consequently it contains the bulk of the small fish that have not been fished to the same extent as the larger specimens. The fishermen have themselves introduced a minimum size of 23 cm.

If we examine the age-group distribution during the period in question, as shown in Figure 17, we find that the proportion of older flounders was greatest in 1927 and the distribution of groups IV—VI was comparatively uniform. This was also the case in 1930, but in 1933, 1937, and 1938 a change took place; group IV became more predominant and the older year-classes were less well represented. Concurrently with some improvement in the post-war landings the V-group was again present in 1948. The year 1949 was characterized by a strong III-group and no flounder older than group V occurred in the catches. Although the older year-classes of the flounder lost in importance concurrently with the depletion of the stock, the general distribution of the year-classes seems to have been somewhat more uniform than, for instance, in the plaice, nor is the number of the year-classes so restricted. In other words, the stock of flounder does not appear to have been so fully exploited as that of the plaice. The larger numbers of young fish (groups III and IV) in the landings in recent years should be regarded in the light of the great increase in the growth of the flounder, which has resulted in the fish reaching the size at which they can no longer escape through the mesh of the trawl at an earlier age than before.

As regards the relative strengths of the various year-classes, group IV was fairly prominent in 1933 and 1938, and group III in 1949. It seems justifiable to assume that these groups represent good, though not particularly strong, year-classes.

A comparison between the strengths of the year-classes and the

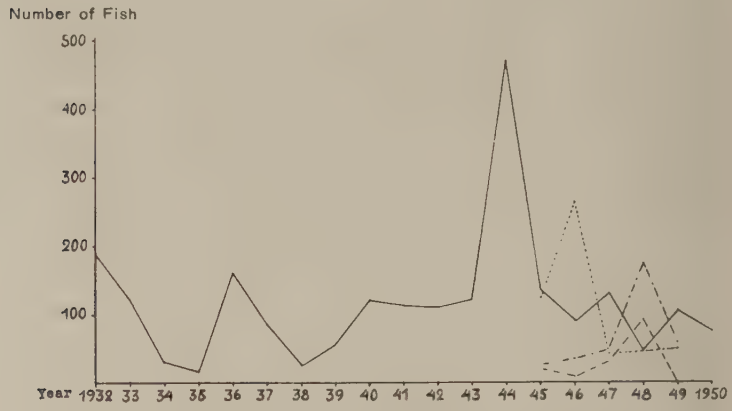

Figure 18. Average catch of 0-group flounder.
Coastal region of Bornholm (Danish investigations with hand push net) ____
Coastal region of Scania and Blekinge (Swedish investigations with the Johansen trawl) southern Scania - - - - - - - -
eastern Scania - · - · - · - ·
Blekinge · · · · · · · · · ·

occurrence of the 0-group off the coasts of Sweden and Denmark does not lead to a firm conclusion. Figure 18 illustrates the figures given by the Danish investigations (Ann. Biol., **2—6**) for the average landings of 0-group fish from the coastal region of Bornholm per 30 minutes' fishing with the hand push net over the period 1932—51. The occurrence of the 0-group varies considerably, and in some years, e.g., 1944, the catch is very large. The figures from Swedish investigations are also shown in Figure 18 but only for the years 1945—49 (Ann. Biol., **3—6**). The Swedish investigations were made with the Johansen trawl off the south and east coasts of Scania and in the Blekinge skerries. No definite correlation is evident between the occurrences of the 0-group as shown by the Danish and Swedish investigations, nor between the Swedish landings at Scania and Blekinge. The existing data, therefore, do not permit us to establish a connexion between the strength of the 0-group off the coasts and the strength of the year-classes in later years. That a connexion does exist, however, seems likely, even though the very divergent results shown in Figure 5 do not directly support this view. The marked prominence of the III-group in 1949 may have resulted, for instance, from the abundance of the 0-group off the Blekinge coast in 1946. However, the relatively high numbers in groups IV and V in 1948 may be due to the good stock of 0-group off the coast of Bornholm in 1944 and 1945, as shown by the Danish investigations. At all events, good 0-groups appear to have occurred much more regularly off both Danish and Swedish coasts than they did in the case of the

plaice. A consequence of this is that a fairly uniform contribution has been made to the year-classes which safeguard the continued existence of the stock within the framework of the annual recruitment.

Age and Growth of the Flounder.

Data on the age and growth of the flounder are available from the Swedish investigations in the 1920's and 1930's and have been published (Rapp. et Proc.-Verb., **108**, 1938). Recent Swedish investigations, however, relate only to the years 1948 and 1949. Table 4 gives the results of age and growth determinations made for flounder from the southern Baltic taken in spring in the course of these investigations. As some of the samples were comparatively small, the averages obtainable are not

Table 4. Average length of flounder by age-groups in different years.

Year	Month	Sex	Age-Groups III	IV	V	VI	VII	VIII
1927	May	♂	23·0(1)	24·7(11)	26·5(11)	27·5(6)	26·0(1)	—
		♀	—	25·2(2)	25·0(2)	31·4(5)	30·2(2)	—
1930[1])	Febr.	♂	20·8(24)	23·8(22)	26·1(21)	30·2(2)	32·0(1)	—
		♀	22·0(1)	26·4(10)	29·5(17)	30·8(5)	34·5(2)	33·0(1)
1933[1])	Febr.	♂	21·9(11)	23·8(56)	26·0(7)	—	—	—
		♀	21·5(2)	26·1(44)	29·3(16)	—	—	—
1937	March	♂	23·0(3)	28·4(5)	26·0(1)	30·0(1)	—	—
		♀	26·0(1)	27·4(3)	31·6(6)	35·0(2)	—	—
1938	March	♂	22·6(3)	26·5(13)	—	—	—	—
		♀	22·0(2)	28·9(10)	32·5(10)	33·6(4)	—	—
1948	March	♂	20·5(5)	26·0(3)	30·5(5)	—	—	—
		♀	26·0(4)	30·2(10)	36·0(8)	39·2(2)	41·0(1)	—
1949	April	♂	23·7(65)	30·7(18)	35·7(3)	—	—	—
		♀	26·4(23)	31·1(27)	38·9(16)	—	—	—

[1]) A new winter-ring was in course of formation or nearing completion, so that a new year-class has been included here.

always fully reliable. The information appearing in the table is illustrated in Figures 19 and 20. It may be seen that at one period the flounder experienced a very considerable increase in size and growth, as compared with the figures for 1927, for instance, or for 1948—49. By the early 1930's the higher growth-rate had not become evident (cf. 1939, 1933); the stock, however, was then still abundant. But in 1938 (Figure 20) a distinct change took place in the growth-rate of the flounder and in the average length of the age-groups, concurrently with a sharp reduction in the landings. This feature became still more clearly marked in 1948—49, and at this time the state of growth was reached which is now regarded as characteristic of the flounder. Meanwhile the stock was still further depleted, reaching a level that has remained comparatively uniform since the late 1940's. As already mentioned,

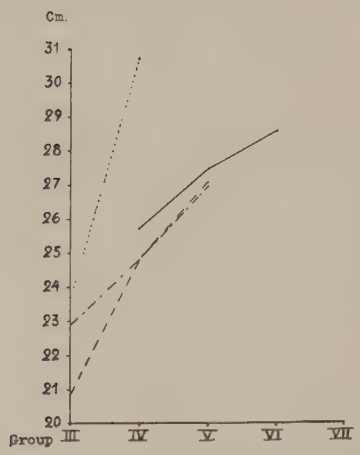

Figure 19. Average length of age-groups of male flounder from the southern Baltic.
May 1927—— Febr. 1930 - - -
Febr. 1933 - · - · April 1949 · · ·

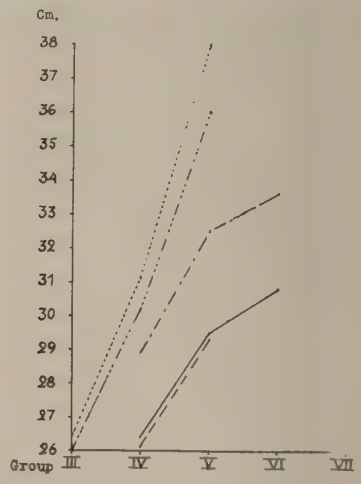

Figure 20. Average length of age-groups of female flounder from the southern Baltic.
Febr. 1930 ——— March 1948 - · · ·
Febr. 1933 - - - - - April 1949 · · · · · ·
March 1938 - · - ·

the stock is now entirely dependent on annual recruitment, but the sharp increase in annual growth should to some extent counteract the heavy demands of the fishery and should help to maintain the level of the stock.

Females grow more quickly than males (Figures 19 and 20) and they outnumber the males in the older year-classes. It also seems clear from a comparison of the sizes of the flounder in various years that the increase in growth-rate is more accentuated in the higher age-groups. This is probably a consequence of the greater efficiency of the fishery in so far as the larger flounder are concerned (Table 1); these occur in localities in which large-scale trawling can be prosecuted. The younger fish (groups II and III) still live mainly in coastal regions where no trawling can be carried on, and some protection is thus afforded to the growing stock of flounder (cf. M o l a n d e r, Rapp. et Proc.-Verb., **78**, 1932).

Conclusions.

Landings of flounder in the southern Baltic fell sharply from the end of the 1930's until quite recently. Nowadays the stock of flounder which makes its limited tribute to a reduced fishery is very much depleted. The surplus formerly present in the stock has now disappeared and the stock is maintained chiefly through annual recruitment. This appears to be slightly more uniform than it was found to be for plaice,

primarily owing to the fact that the flounder has more favourable living conditions and is also better protected against the inroads of the fishery during the growing period. In recent years, therefore, the flounder has been slightly better represented in the supply of fish available in the southern Baltic than the plaice. The depletion of the stock has nevertheless continued up to the present time, as the very vigorous growth of the flounder in the various year-classes shows. The stock is better able to withstand the fishery by reason of the much higher growth-rate; the recruitment of the stock and the renewal of the fishery supplies are hastened thereby. Although the stock is much reduced, it appears to be maintained at a level which, at least for the present, guarantees the fishery a comparatively uniform, but not high yield, allowance being made for the fluctuations caused by the emergence of year-classes of varying strength. Since other fisheries are more profitable it does not pay to intensify the flounder fishery on the present stock in the southern Baltic, and, accordingly, a certain balance is maintained between the fishery and the supply of fish.

On the Autumn-Spawned Herring Races of the North Sea.

By

D. H. Cushing.

Introduction.

Herring "races" are probably of phenotypic origin, in that differences between them may be attributed to differences in conditions on the spawning ground; e. g., differences in temperature on the spawning ground might well be associated with differences in mean vertebral counts and other meristic characters. Other differences between "races" are differences in l_1 and maturity stage, which are probably the consequence of differences in time of spawning. Herring "races" are usually characterized by a combination of the latter temporal differences with the former meristic differences.

Fisheries biologists are interested in such racial differences only in so far as they produce heterogeneous estimates or mortality-rates, growth-rates, and recruitment-rates. If there are a number of "phenotypic races" living under the same conditions of feeding and spawning and subject to the same distribution of fishing effort, then their vital parameters are likely to be more or less homogeneous. Differences in the distribution of effort may lead to differences in the rates of fishing mortality, differences in feeding grounds may result in differences in growth-rate, and differences in spawning and nursery grounds may effect differences in the rate of recruitment.

An attempt will be made to distinguish between the Bank herring, contributing to the Fladen, Gut, Dogger, Bohuslän, and part of the Scottish N. E. coast fisheries, and the Downs herring, contributing to the East Anglian, Sandettié, Boulogne, and Ostend fisheries, and possibly to some of the summer fisheries in the central and northern North Sea. If such a distinction can be made, there are clearly major differences in the distribution of fishing effort and there are also possibly differences in growth-rate (personal communication, A. C. Burd). There are

certain fisheries, notably the Whitby, Dowsing, and Bløden grounds, which are either mixed fisheries or at the moment are unassignable to the two major groups.

Arguments for the Separation of two Main North Sea Stocks.

1. Spawning grounds.

The known spawning grounds of the herring in the North Sea are shown in Figure 1 (from Bowman, 1922; Fulton, 1891; Poulsen, 1932; Johansen, 1924; Hodgson, 1928; Runnström, 1935; the work on post-larvae by Wallace, 1924, and Bückmann, 1942, has also been consulted); Figure 1(a) shows the spring-spawning grounds and Figure 1(b) shows the autumn- and winter-spawning grounds. With the exception of the Firth of Forth stock, spring spawners do not spawn in the main part of the North Sea; hence we can regard the North Sea herring proper as an autumn- or winter-spawning fish, and the remainder of this paper will be concerned with this, the North Sea herring.

The main autumn-spawning grounds are found west of 3°E., in general within the 40-fathom line. Those north of the Dogger have been located by means of trawl-caught "spawny haddocks". There are few haddocks south of the Dogger and so location has had to depend upon the less certain method of charting the distribution of yolk-sac larvae. There are three main spawning areas, the Scottish east coast, the Dogger region (including the Whitby, Shields, Silver Pit, and Dowsing grounds) and the Straits of Dover (extending perhaps from the "Galloper" light-vessel to Cap d'Antifer). Spawning takes place in the first two areas at the same time, August to October, but there is no spawning in the Straits until November. This fact alone should lead us to believe that there would be differences in l_1, vertebral count, and maturity stage between the northern autumn-spawning fish and the southern winter-spawning ones.

2. Vertebrae.[1])

The use of vertebral counts presupposes two assumptions. The first is that the number of vertebrae of any one fish is affected slightly by the conditions on the spawning ground. The second assumption is that a mean vertebral count is from an unmixed sample of fish, all of which are native to the same spawning ground. The number of frequency classes in such a sample is usually so small that tests of polymodality are not reliable. The best chance of obtaining an unmixed sample is to take it on the spawning ground, though this may not always be possible. Dr. Hodgson tells me that fish may not always spawn on their native grounds, for Norwegian fish identified from their scale type and length-for-age have appeared in the East Anglian fishery. Again, Mr. Burd has shown that the proportion of autumn-spawned

[1]) The information in this section has been taken from the *Annales Biologiques*, 5—9, and Hempel (1954); authors are referred to individually in the Bibliography.

Figure 1a. Herring spawning grounds in the North Sea. Spring-spawning grounds (from Bowman, Poulsen, Runnström).

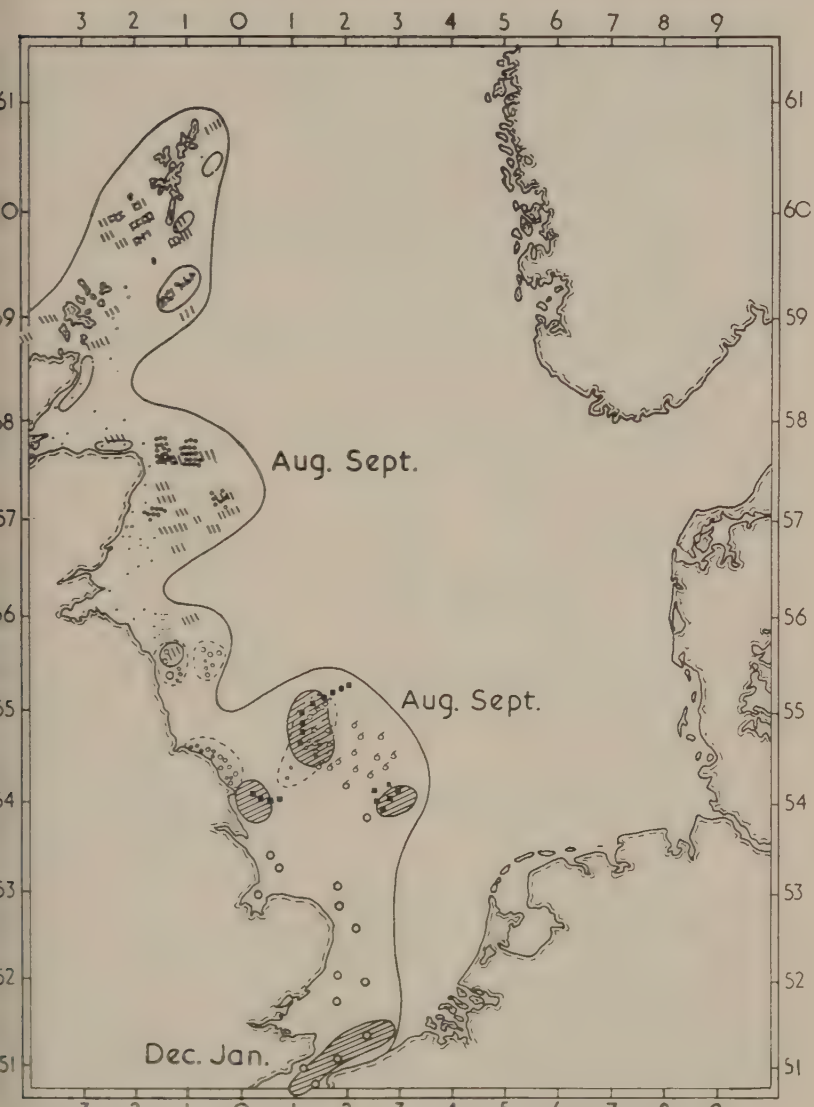

Figure 1b. Herring spawning grounds in the North Sea. Autumn-spawning grounds (from Fulton, Bowman, Wallace, Johansen, Hodgson, Runnström, Bückmann). Observations south of 54°N. are of yolk-sac larvae.

fish in the East Anglian fishing changes to a certain extent from year to year. However, many of these errors will be minimized if samples are compared each year over a number of years; we are comparing the degree of difference obtained each year over a number of years, rather than the actual vertebral counts.

Table 1 gives the means of vertebral counts from samples taken on spawning or pre-spawning grounds. The Fladen and Gut are not known to be spawning grounds, but these fisheries may be on pre-spawning aggregations. It has been a fairly common observation that echo-traces of herring on the trawling grounds are scarce and yet catches are high. Recently, in a limited number of observations, Mr. Richardson has found that catches with a Dutch trawl are associated with little or no echo-trace on the trawling grounds and that shots with the trawl on strong traces on drifter grounds yield little or no catches.

Table 1.

Vertebral counts of samples from major North Sea grounds.
(From several authors).

Year	Fladen	Gut	Dogger	East Channel	Ostend
1948	56·47, 56·40	—	56·48	56·67, 56·58	56·56
	(226), (418)	—	(279)	(288), (256)	(694)
1949	56·55	56·43, 56·44	56·50, 56·40	56·58, 56·61, 56·70	56·61
	(174)	(131), (101)	(392), (343)	(331), (286), (457)	(614)
				Sand- Bou- Dieppe ettié logne	
1950	56·37	56·48	56·50	—	56·58
	(393)			—	(680)
1951	56·53	—	—	56·42, 56·63, 56·59	56·57
	(432)	—	—	(282), (284), (129)	(942)
				Sand- Bou- Dieppe ettié logne	
1952	56·45	56·53[1])	—	56·50, 56·55 —	56·59
	(468)	(248)	—	(289), (166) —	(674)

[1]) Mixed sample of maturity stages IV and VII.
The numbers in brackets indicate the numbers of counts made; where none is given, the original publications quote the standard deviation, variance, or the standard error of the mean.

From Table 1, it is concluded that in any one year, the vertebral counts of samples from Boulogne and Ostend with one exception are always higher than those of samples from the Fladen, Gut, or Dogger.

Samples from the East Anglian fishery have not been included because the fishery is not strictly on a spawning ground; also, Mr. A. C. Burd believes from his work on I_1's that there is a certain admixture of fish spawned in the autumn on the Dogger every year into the fishery. This is not unreasonable, for Wallace (1924) showed that the post-larvae from the Dogger and Channel spawning grounds

mix to a certain extent. Thus we should expect that the mixture would be shown in the vertebral counts, the East Anglian count being intermediate between the Dogger and the Channel groups. The admixture, in numbers, is perhaps of the order of 20 %; in some years it may even amount to over 50 % in certain age-groups. The means of vertebral counts from the East Anglian fishery from 1948 to 1952 are shown in Table 2.

Table 2.

Vertebral counts of samples from the East Anglian fishery.
(Personal communication, A. C. Burd)

1948	1949	1950	1951	1952
56·53, 56·59	56·59, 56·49	56·51, 56·54	56·57	56·56, 56·53
(657) (291)	(973) (514)	(1597) (739)	(399)	(1431) (316)

Anomalous results appear from time to time. On the Fladen ground, in 1950, the mean vertebral counts were as follows (the maturity stages are also given):—

	V. S.	N.	Maturity Stages
August	56·58	119	III IV V
September	56·67	100	III IV V
October	56·37	393	VII

(Wood, 1951)

From the vertebral counts and maturity stages, the August and September samples could possibly be of Downs herring whereas the sample taken in October is probably one of Bank herring. From Hempel's work (1954) it is possible that herring of this type appear in the northern North Sea more frequently than this single sample might suggest.

Gilis has separated two groups of herring in the North Sea caught on the Fladen, Gut, and Dogger. They have been separated by vertebral counts and maturity stages as shown in Table 3. A similar separation was made by Furnestin (1936).

Table 3.

Separation of Gilis's Group 1 and Group 2 as mean vertebral counts at different maturity stages.

	Group 1 (Maturity stages I-III)	Group 2 (Maturity stages IV to VII-II)
1948	56·81	56·50
1949	56·74	56·52
1950	56·56	56·49
1951	56·81	56·51
1952	56·51	56·52

We need not specify for the moment which "race" Group 1 corresponds to, but Group 2, by reason of mean vertebral count, maturity

stage, and position of capture are almost certainly fish from the Fladen, Gut, and Dogger group.

Subsequent argument, following Johansen (1924), Andersson (1950), and Höglund (1954) will link the winter fishery for autumn spawners off Bohuslän with the Fladen, Gut, and Dogger group. For comparison with Table 1, vertebral counts from samples of recovering spents taken in the Bohuslän fishery are given in Table 4; these fish are autumn spawners, the scales of which have "small central fields".

Table 4.

Mean vertebral counts of samples of recovering spent autumn spawners from the Bohuslän fishery.

1947-48	1948-49	1949-50	1950-51	1951-52
56·32, 56·49 (73), (99)	56·46 (389)	56·45 (472)	56·44 (243)	56·47 (352)

3. The connexion between the Bohuslän fishery and the Fladen, Gut, and Dogger group of autumn spawners.

The possibility of this connexion was raised by Johansen (1924). He separated the Bohuslän autumn spawners from the Norwegian spring spawners and Kattegat winter spawners by the higher vertebral counts of the two latter "races" and their differing maturity stages. His argument is really based on the following mean vertebral counts, Table 5.

Table 5.

Mean vertebral counts from the Bohuslän fishery, as quoted by Johansen, 1924.

Date	Locality	V. S.	Error of Mean	Maturity	Author
Jan. 1891	Skagerak	56·60	—	Recovering spent	Heincke
Jan. 1905	Bohuslän	56·44	—	„ „	Brock
Feb. 1915	Vinga	56·47	—	„ „	Johansen
Mar. 1915	Skagen	56·54	0·05	„ „	„
Jan. 1924	„	56·53	0·07	„ „	„
„ „	„	56·50	0·07	„ „	„
„ „	„	56·45	0·06	„ „	„
„ „	„	56·38	0·06	„ „	„
Mar. 1923	„	56·33	0·06	„ „	„

This evidence combined with that given in the previous section is not inconsistent with the thesis that the fish caught from pre-spawning aggregations on the Fladen, Gut, and Dogger in the late summer and early autumn are similar to those caught at Bohuslän six months later as recovering spents.

Independent and rather clearer evidence of the connexion between the Bohuslän fishery and that on the Fladen in late summer was presented by Andersson (1950). I have reproduced his figure here as Figure 2. Two dominant year-classes, those of 1939 and 1941, provide a fortuitous common character to the two fisheries from 1945

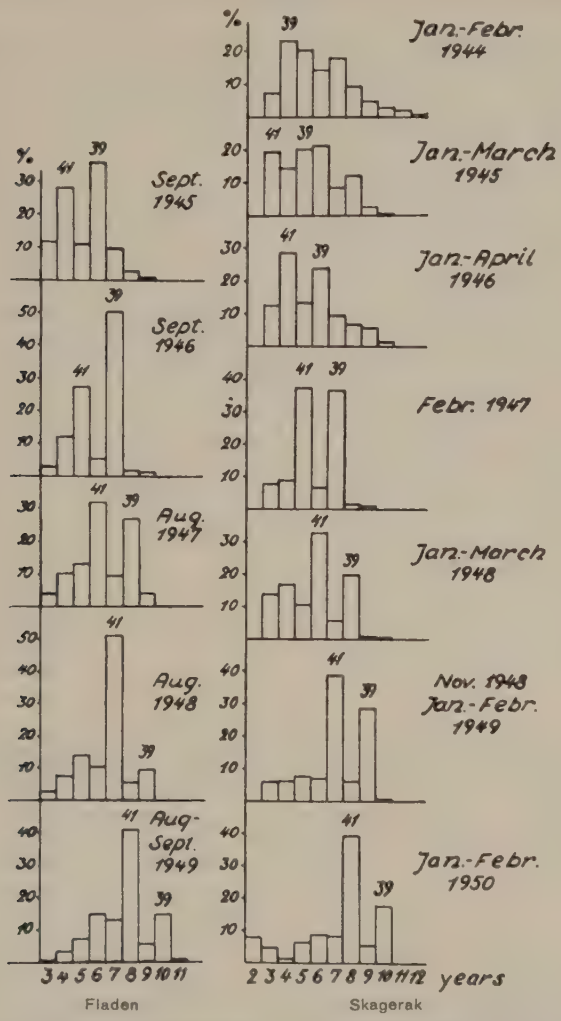

Figure 2. Age composition from the Fladen and Bohuslän fisheries (from Andersson, 1950). It is to be noted that the fish caught on the Fladen (Aug.—Sept.) have one more growth-zone than fish caught at Bohuslän (Jan.—Apr.) in any one year.

to 1949. Such age distributions have not appeared in East Anglia, or off Boulogne or Ostend.

It will be recalled that the Bohuslän fishery takes place from January to March, whereas that on the Fladen in late summer takes place after

another year's feeding and after an extra growth-zone has been laid down. Hence fish with 7 growth-zones at Bohuslän correspond to one with 8 growth-zones on the Fladen. The conclusion from this remarkable figure is that fish living on the Fladen in August move to Bohuslän by the next January and then seven months later arrive back on the Fladen.

4. Evidence from tagging.

Tagging results, as shown in Table 6, show which way the fish move from the Fladen to Bohuslän.

Table 6a.

Time-table of returns of fish tagged in the Skagerak in early spring and on the Dogger in September.

The Dogger returns are in italics to distinguish them from the Skagerak returns. (From Höglund, 1954.)

Locality	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Skagerak	—	—	—	—	—	—	*1*	*6*	*1*	—	*1*
Egersund Bank	—	5	2	—	—	—	—	—	—	—	—
Fladen	1	8 *1*	4	—	—	—	—	—	—	—	—
Gut	—	—	4	1	—	—	—	—	—	—	—
Dogger	—	—	16 *2*	22 *4*	4	—	—	—	—	—	—
Whitby	—	—	3	1	—	—	—	—	—	—	—
W. Hole	—	—	—	—	1	—	—	—	—	—	—
Winterton	—	—	—	—	*2*	—	—	—	—	—	—
Sandettié	—	—	—	—	*3 3*	*1*	—	—	—	—	—
Horns Reef	—	—	—	—	—	—	—	1	—	—	—
Hanstholm	—	—	—	1	—	—	—	—	—	—	—

Table 6b.

Position of distant recapture and days at liberty (in brackets) of fish tagged on the Scottish north-east grounds in summer.

(From Wood, 1951; Wood *et al.*, 1952; Parrish *et al.*, 1953.)

Year	Total Recaptures	Gut	N.E. Coast England	N. Dogger	E. Anglia	Skagerak
1950	12	—	1(105)	3(68—102)	—	1(257)
1951	92	7(18—100)	4(83—131)	9(74—142)	2(178—237)	1(263)
1952	175	9(7—103)	4(36—113)	14(26—161)	3(123—135)	1(206)
1953	—	3	4	5	1	2

From Table 6a, it is clear that fish tagged in the Skagerak in early spring were caught in late summer and autumn on the Fladen, Gut, Dogger, and Hanstholm grounds, and at Sandettié in that order. Again, fish tagged on the Dogger in September were caught in the Skagerak the next spring and on the Fladen a year later. This is the basis for Höglund's thesis (1954) that the fish move round the North Sea once a year. The same sequence of events may be seen from Table 6b which gives a time-table for fish tagged on the Scottish north-east grounds in summer.

Between 1951 and 1953 fish were also tagged on the Shetland and Orkney grounds in summer; 84 fish were returned from the Scottish

north-east coast, the Fladen, the Dogger, and the Skagerak, but none in the three years was returned from any fishery south of the Dogger. Hence fish can make the circulation of the North Sea without moving south of the Dogger, yet fish tagged on the Dogger move to Sandettié and Bohuslän, and fish tagged at Bohuslän appear at Sandettié.

From the Dogger tagging experiment, fish appear at Sandettié in December and January, and in the Skagerak mainly in January and February (7 returns, whilst one reached Skagerak in March and another in May). It seems unlikely that the same fish could reach Sandettié and the Skagerak at about the same sort of time. It is more probable that on the Dogger it is possible to tag fish some of which will reach Sandettié and others of which will reach the Skagerak, both after an interval of three or four months. It is significant that fish tagged at Sandettié in December and February appear at the Silver Pits in March (2 returns, personal communication, G. C. Bolster).

As fish of intermediate maturity stage and high vetebral count can be found in the central North Sea in summer (Furnestin, 1936; Gilis, 1949a, 1950, 1951a, 1952a, 1953a; Hempel, 1954), it is not unreasonable that fish tagged off the Scottish north-east coast should be returned from East Anglia (which includes any position from the Dowsing to Sandettié). It is, however, remarkable that 2 fish tagged in the Skagerak appeared at Sandettié in 1951 and 1952 and 1 fish appeared on the East Anglian grounds (1951); it is possible that this is associated with two remarkable facts, first, that the mean vertebral count at Sandettié in 1951 was 56·42 (see Table 1) and, second, that the proportion of 11 and 14 cm. l_1's exceeded the 9 cm. l_1's winter spawned in the East Anglian fishery.

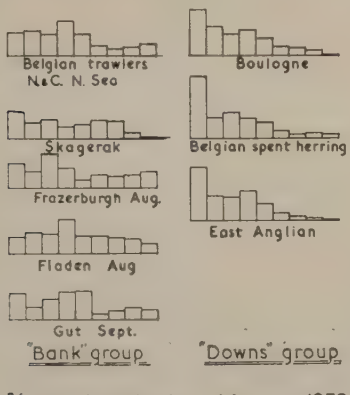

Figure 3. Percentage age distributions of North Sea herring in 1952. The ages are not shown on the diagrams because they are not so comparable, as the fisheries extend from January 1952 to January 1953.

5. Age distributions of the two groups.

Figure 3 gives the age distributions of fish caught in a number of fisheries in 1952. The samples from Frazerburgh in August were composed of late maturity stage fish, presumably being composed of fish

Figure 4. Positions of herring samples taken from cod liners, 1930—34 (from Savage, 1937).

that would spawn in August or September. The age distributions given are not comparable exactly because I have used the Bohuslän samples for February 1952, the summer samples for 1952 from the northern and central North Sea, and the Boulogne and Ostend samples for

1952—53. This, however, does not matter, for the point is in the differences of shape in the age distributions; the proportions of fish in each age-group of the Bank herring are not very different, whereas there is a marked preponderance of younger fish in all three samples of the Downs herring. The age distributions of the groups of fisheries are so different that one must conclude that they are either different stocks or the same stock subjected to different effort in the different fisheries.

6. The spring movements of autumn-spawned herring.

There are some indications of how the fish move on the feeding grounds in the productive areas north of the Dogger Bank and north-west of the Great Fisher Bank, although knowledge of the movement is less than adequate.

In his work on the food of the North Sea herring, S a v a g e (1937) took his samples firstly from the Shields fishery and secondly from cod liners working between the Viking Bank and the Great Fisher Bank on the western edge of the Norwegian Rinne. Each vessel shot a few drift-nets for herring to be used as bait. Figure 4 shows the positions from which herring samples were obtained from cod liners. Hence, herring are to be found between the Skagerak and the northern North Sea feeding grounds in April, May, and June. However, as the vessels were cod liners, the figure only shows the presence of herring in the area and not its absence outside it.

The Shields fishery rarely starts before the end of April or the beginning of May. Before this time the fish are not there. This has been shown on two series of echo-surveys in 1949 and in 1954. The first was carried out from Berwick to Whitby between April and June 1949 (C u s h i n g, 1953) and the second was carried out from the Devil's Hole to Whitby between mid-March and June 1954. In both years, echo-traces were not observed in any quantity in the Shields area until the end of April and these appeared in the south of the region on the north-western slopes of the Dogger. Hence, it is unlikely that the fish came from the north or the north-east.

There are thus two groups of fish in spring, one on the edge of the Rinne and one on the edge of the Dogger. If we consider that the Downs herring are to be found in winter near the Straits of Dover and that at the same time the Bank herring are to be found in the Skagerak, it would not be unreasonable to suppose that in April the Downs group had reached the Dogger and the Bank group had spread all up the Rinne. Echo-traces of fish are not found in the region just north of the Dogger until the end of April, whereas some of S a v a g e' s samples from the edge of the Rinne were taken at the beginning of April, when the fish were feeding vigorously.

7. The feeding fisheries and maturity.

Feeding grounds in the North Sea lie in the west, in the southward stream of the larger *Calanus* from Fair Isle to Flamborough. In May

and June, the larger copepodite stages of *Calanus* are found predominantly in this region and here Scottish, English, and Dutch drifters congregate, as shown by the monthly distribution charts of effort (*Annales Biologiques*, **5—9**). It is thought that the distribution of effort will give a rough guide to the distribution of the larger fish shoals.

Studies at present in progress at Lowestoft show that the fat content of herring in the Shields fishery rises from an initial low value to a peak in June or July. This period between the beginning of May and the end of June is the period of most intense feeding (Savage, 1937) and corresponds with the period of feeding on *Calanus*, on which positive aggregation is made (Cushing, in press). Thus, the build up of fat is associated with *Calanus* feeding after the fish appear north of the Dogger. *Calanus* does not exist in appreciable numbers south of the Dogger, and feeding before this time is probably only subsistence feeding.

Savage (1937) shows that the fish found in the northern North Sea on the west of the Norwegian Rinne start feeding on *Calanus* a month or five weeks before the fish that come into the Shields fishery from the south. As the period of very intense feeding lasts only two months (Savage, 1937), this advantage in time is a most significant one. It becomes important when one considers maturity.

As herring feed, the fat content rises rapidly, to be followed by decreased feeding and then maturity proceeds with a decreasing fat content. The fat is probably being used to manufacture sterols in the growing gonad. Now the fish that start to feed first will reach their peak fat content more rapidly and will mature more rapidly. The advance of maturity may be substantial when it is considered that the advantage in time of starting to feed amounts to half the total intensive feeding period.

One of the distinctions between the Downs herring and the Bank herring is by maturity stages; indeed it is obvious when one considers the differences in spawning times. This may well be the basis of the 1 and 2 groups of herring separated by Gilis in the central North Sea. The same distinction may be seen in some of the charts recently published by Hempel (1954), which show fish of high vertebral count and middle maturity stage caught in the Gut in summer.

Discussion.

The autumn spawners in the North Sea have been separated by racial specialists into the Bank herring and the Downs herring. The division is shown to be supported by location of spawning grounds, the comparison of mean vertebral counts from spawning or pre-spawning grounds, by the connexion of the Fladen autumn fishery with the Bohuslän spring fishery, by the very recent results of tagging experiments, and by a comparison of age distributions in North Sea fisheries.

The separation has been found in every kind of data; the mechanism appears to be that the Bank herring move in the path of the central North Sea swirl and in the same direction, whereas the Downs herring

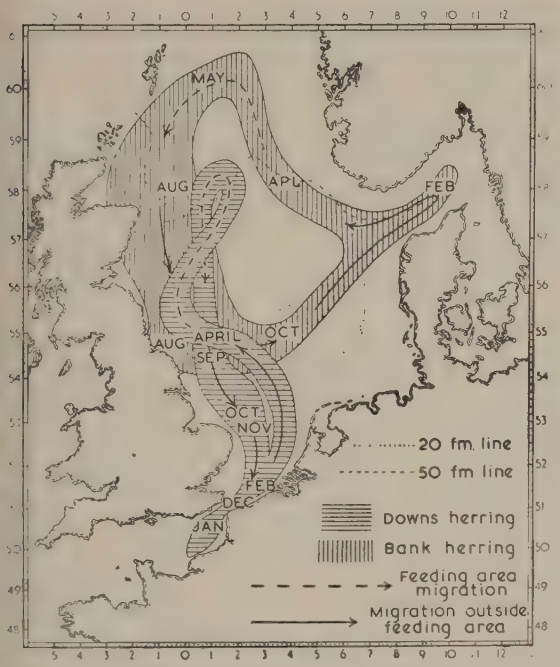

Figure 5. Hypothetical migrations of the Downs and Bank herring in the North Sea. The feeding area for the Bank herring is roughly assumed to be north of the 50-fathom line, between Orkney and Norway. The feeding area for the Downs herring is roughly assumed to be between the Dogger and the Fladen, west of the Gut.

move in this track during part of the feeding season only. The postulated migrations of the two stocks are shown in Figure 5.

The Bank herring are supposed to feed in the northern North Sea, drift south, and spawn between the Fladen and the Dogger from July to September. The spent fish "drift" towards the Skagerak which they reach after Christmas; subsequently they "drift" northwards to the northern feeding grounds. This is the same as Dr. Höglund's suggestion that the herring population of the North Sea revolves once a year; the only difference is that I have confined the "drift" to the Bank herring. Figure 6 shows the movement of autumn-spawning fish into the Scottish summer fishery as deduced by Dr. Wood from the appearance of the 1928 year-class in the age distributions, thus directly confirming part of the postulated cyclical movement.

The Downs herring do not drift all their lives in this way, for three of their movements are against the drift. In November and December they appear to move through the Straits of Dover against the presumed residual current. In early summer they appear to move from the North Dogger northwards against what residual current there is. Lastly, the use of echo-survey has shown that fish can move very rapidly off the S. W. Patch of the Dogger to the region of the Norfolk banks; this

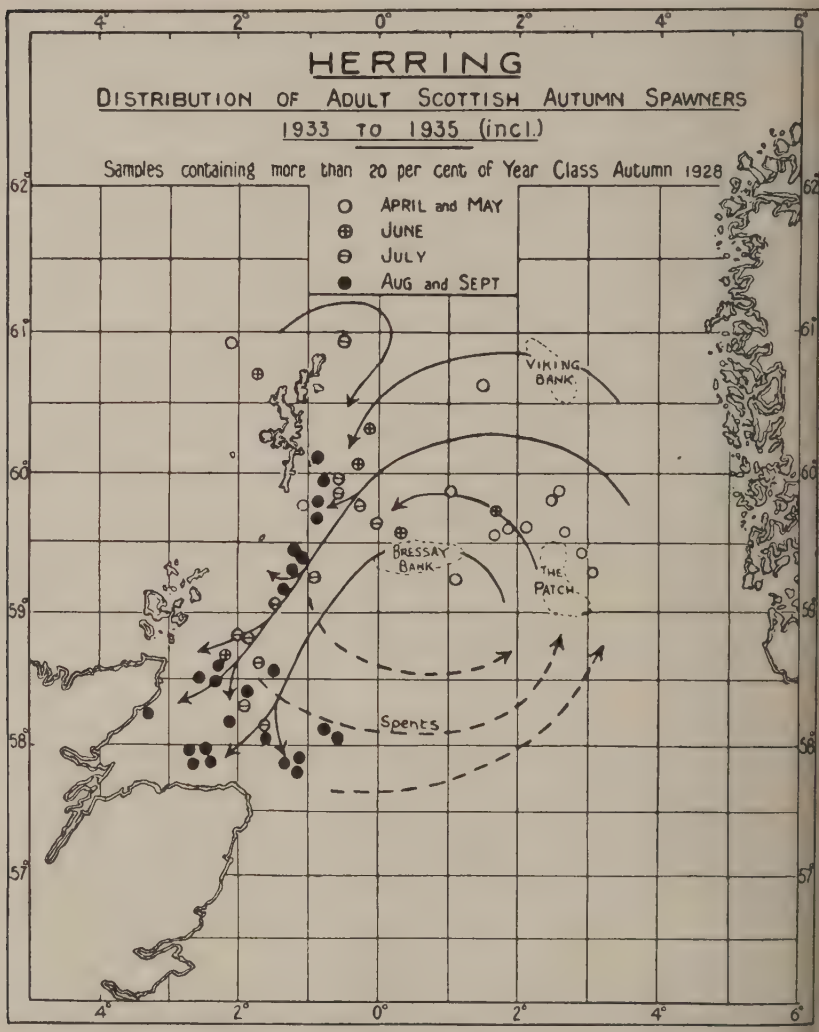

Figure 6. Movement of Scottish autumn-spawned herring, as identified by the 1928 year-class (from W o o d, 1937).

movement is very rapid and is apparently across the presumed residual current.

Where I have written that the Bank herring "drift" round the North Sea, I do not mean that each fish passively drifts. I mean that they move actively, aggregating to feed and spawn, but that the residual

direction of their actual movements corresponds with the direction of the North Sea swirl. Hence, if we were to assume that herring move round once a year, we do not need to know the speed of the swirl but only its direction.

The hypothesis as stated so far is incomplete. No account yet has been taken of differences in growth-rate or in l_1; the application to nursery grounds, the Bløden ground in particular, has not yet been worked out; and lastly, the method of migration is not yet understood. The hypothesis is offered in incomplete form because of the interest now being shown in tagging and of the coming interest in the effect of fishing on herring stocks.

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The Food of Herring on the Bløden Ground (North Sea) in 1953.

By

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DURING the period October 1952—February 1954 (excepting the months of November 1952, and February, May, and June 1953) the stomach contents of 920 herrings from the Bløden Ground were examined. In the present context the "stomach" includes the oesophagus, caecum, and pylorus. Of the stomachs examined, 130, or 14·1 %, were empty.

The main feeding period, during which the fat reserve is formed, lasts from April to July. Only one sample is available for this period and this, unfortunately, relates to the beginning of the period. Of this sample only 1·2 % of the stomachs were empty and the average number of organisms in the stomachs, 295·5, was higher than for any other sample (Table 1 and Figure 1). The maximum number of organisms in a stomach was 660. Fishing ceased in May, when the full stomachs and intestines burst as a result of fermentation during transport to the factory and the catches putrified. No samples for analysis were obtained during this period but from reports received, it appears that the stomachs were filled to a degree never observed in the samples investigated.

In autumn the average number of organisms in the stomachs was about 100; this decreased to between 5 and 40 in winter and early spring. On an average, 95 % of the food organisms found were Crustacea (except in December 1952 and March 1953). From April to December Calanoida alone made up more than 90 % of the total contents.

Table 2 shows the percentage occurrence of Calanoida, the most important species being *Calanus* (maximum in March and October) and *Temora longicornis* (maximum in April, July, and August). *Pseudocalanus* + *Paracalanus* predominated only in October 1952 and January 1953, and *Centropages typicus* only in autumn 1953. Unidentified Copepoda varied between 1·9 and 47·7 % of the total number of Calanoida.

In summer 1953 Euphausiacea and Hyperiidae occurred in the stomachs either not at all, or only in very small numbers, the highest monthly averages being 1·4 and 1·0 for Euphausiacea (furcilia stage) in March and February and 5·5—3·5 for Hyperiidae (mostly juvenile) in autumn and spring. In September—November 1952 Podoplea

Table 1.

Mean number of organisms in the stomach of herring in each month.

	1952		1953				
	Oct.	Dec.	Jan.	Mar.	Apr.	July	Aug.
Number of stomachs	16	20	143	105	84	81	212
% of empty stomachs	12·5	0	18·9	21·9	1·2	4·9	24·1
Average number of organisms in the stomach	33·4	138·0	10·5	37·4	295·5	119·7	122·1
Crustacea: % of total number of organisms	96·7	79·4	99·2	84·5	98·8	99·8	99·8
Calanoida: % of total number of organisms	95·7	77·8	88·7	65·4	97·3	99·0	99·7
Fish eggs: average number in the stomach	—	—	0·5	5·8	1·6	0·1	—
Fish eggs: % of total number	—	—	4·6	15·5	0·5	0·1	—
Average number in the stomach:							
Euphausiacea (furcilia)	0·1	0·1	0·2	1·4	x	x	x
Hyperiidae (juvenile)	—	1·5	x	5·5	4·0	x	—
% of stomachs infected with *Hemiurus Lühei*	—	—	2·1	6·6	19·0	69·3	47·2

	1953					1954
	Sept.	Oct.	1-3/11 Nov. I	22-25/11 Nov. II	Dec.	Feb.
Number of stomachs	64	38	20	17	30	49
% of empty stomachs	14·1	0	0	11·8	33·3	2·0
Average number of organisms in the stomach	35·4	87·9	83·9	15·1	4·3	116·9
Crustacea: % of total number of organisms	98·1	100	100	99·9	95·3	93·4
Calanoida: % of total number of organisms	95·9	90·9	95·8	98·2	92·9	88·7
Fish eggs: average number in the stomach	—	—	—	—	—	7·8
Fish eggs: % of total number	—	—	—	—	—	6·6
Average number in the stomach:						
Euphausiacea (furcilia)	x	0·5	x	0·3	—	1·0
Hyperiidae (juvenile)	x	3·5	0·7	—	x	4·3
% of stomachs infected with *Hemiurus Lühei*	21·9	10·2	10·6		13·3	—

(*Oithona* and *Corycæus*) constituted 1·9—4·5 % of the number of food organisms. *Podon*, *Evadne*, and larvae of bottom invertebrates and fish were never of any importance. Fish eggs were eaten in fairly large numbers in January—April. In March 1953 the average number of eggs in the stomachs was 5·8 (15·5 % of the total number of organisms), of which 90 % were those of plaice. In February 1954 only 50 % of the eggs were plaice the remainder being those of Gadidae.

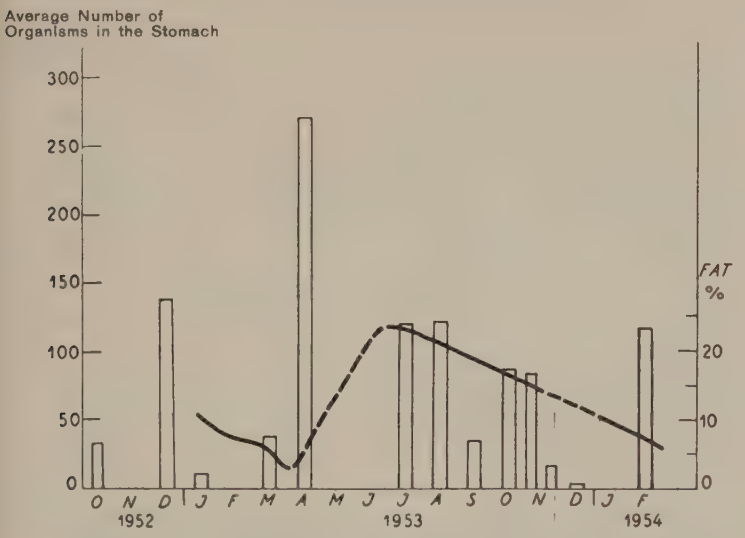

Figure 1. The percentage of fat in the herring (curve), and the monthly average number of organisms in the stomachs (columns) from October 1952 to February 1954.

Table 2.

The percentage composition of Calanoida present in the stomachs.

	1952		1953				
	Oct.	Dec.	Jan.	Mar.	Apr.	July	Aug.
Calanus	1·3	19·6	14·3	73·0	0·3	3·5	13·1
Pseudocalanus + Paracalanus	91·7	19·8	55·2	0·5	1·5	13·3	6·2
Temora longicornis	4·7	41·1	28·6	9·3	74·1	72·2	74·5
Centropages typicus	0·4	4·0	—	—	—	x	0·1
Centropages hamatus	—	—	—	—	—	x	x
Acartia longiremis	—	0·6	—	—	—	x	x
Acartia Clausi	—		—	—	—		0·1
Metridia lucens	—	—	—	—	—	—	—
Pareuchæta, Candacia, ect.	—	—	—	—	—	—	—
Copepoda unidentified	1·9	14·9	1·9	17·2	23·1	11·0	5·9

	1953					1954
	Sept.	Oct.	Nov. I	Nov. II	Dec.	Feb.
Calanus	19·4	74·1	4·9	22·4	17·4	49·1
Pseudocalanus + Paracalanus	1·7	7·6	3·9	24·7	10·0	6·3
Temora longicornis	4·6	7·9	3·5	7·2	3·8	9·9
Centropages typicus	49·6	3·3	85·2	—	30·0	0·1
Centropages hamatus	4·2	0·1	—	—	—	—
Acartia longiremis	—	0·1	0·4			
Acartia Clausi	3·8				28·8	—
Metridia lucens	—	0·3	—	—	—	22·8
Pareuchæta, Candacia, ect.	—	—	—	—	—	1·3
Copepoda unidentified	16·7	6·6	2·1	45·7	10·0	10·5

The seasonal variation of the percentage of the fat content in the herring exhibits a fairly good correlation with that of the average number of organisms in the stomachs (Figure 1). During the vigorous feeding period, from April to July, the fat content rises from a minimum of about 3 % to a maximum of about 23 %. Over the rest of the year the fat content in the herring steadily declines. This indicates that feeding alone is insufficient to provide for the metabolic process, as the herring is constantly using the accumulated reserve of fat. This hypothesis is supported by the following considerations.

The length of time taken by the herring to empty its alimentary tract is 20—30 hours at 6—10°C. (the length of time increases rapidly with decreasing temperature) (S a v a g e, 1937, p. 38). The ratio, content of oesophagus + caecum + pylorus: content of intestine, is 3 : 2. With the exception of the vigorous feeding period from April to July, and the winter (November—January) when conditions are very poor, the quantity of food taken in 24 hours corresponds to 7—20 mg. fat (O r r, 1934).

Active pelagic fish have a metabolic rate of about 90 ml. O_2/Kg./hour. The quantity of food taken by the Bløden herring from August to April is then equivalent to 15—45 ml. O_2/Kg./hour, which covers only 17—50 % of the metabolic requirements.

The energy liberated by combustion of the fat reserves during the period August—April is almost equivalent to the above-mentioned oxygen consumption during the same period at 6—8°C. By using its fat reserve the herring is thus able to cover its energy requirements in 8 months of the year, in spite of the rather low — often very low — feeding rate. This is possible at temperatures between 6° and 8°C. and would appear to have some bearing on the presence of the herring in the tongue of cold bottom water on the Bløden Ground (A n d e r s e n, 1954).

A comparatively small rise in temperature from 7 to 11°C. effects an increase in metabolism of about 50 %. Consequently it is to be expected that the feeding rate would be higher than is actually found, the rate of consumption of the fat reserve being the same as at lower temperatures.

Parasites.

The occurrence in the stomachs of the digene trematode *Hemiurus Lühei* varied during the year (Table 1). In winter it was found in few of the stomachs, the maximum occurrence being in summer. In July the parasite was found in 69·3 % of the herrings, the maximum number in a stomach being 62.

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Temperatures and Mackerel Movements in the Inshore Waters of Torbay, Devonshire.

By

L. A. J. Jackman and **G. A. Steven.**

THE part played by temperature in regulating mackerel migrations has long been discussed. As early as 1877 Browne Goode (1879, p. 65) stated that as soon as the water at a given point reaches a temperature of about 45°F. (7·2°C.) the fish make their appearance on the usual fishing grounds along the Atlantic coast of North America. In 1893 Green (1894, p. 357) reported that mackerel off the west coast of Ireland are not caught in the open sea until the sea temperature reaches 50°F. (10·0°C.). He noticed, however, that mackerel are often caught inshore two or three weeks earlier while the temperature is still low, but no figure is given. His suggested explanation of this anomaly is that some mackerel, on approaching the coast, keep deep down, but that some fish, in advance of the main shoals, are forced upward, against their inclination, by the rise of the sea floor into shallower and colder water near the shore. Otherwise, according to Green, the fish do not rise into the upper waters until there is a suitable surface temperature. This author also pointed out that in America the mackerel fleet goes south to Cape Hatteras to meet the mackerel "which apparently migrate from south to north"; and that although the coast of Ireland is 20° farther north than Cape Hatteras, the same isotherm reaches the two places about the same date so that the Irish and American spring mackerel fisheries open simultaneously. Johansen (1925) and Jensen (1930; 1933, p. 56; 1939, p. 75) have shown that surface temperatures often become high enough to prove a deterrent to mackerel entering the fishing grounds in the Kattegat and that, in general, the lower surface temperatures down to between 11° and 12°C. in June and July give better prospects for the fishery. These temperatures are determined by the strength of the inflow of water into the area, which in turn is influenced by a number of factors, chief among them being the direction and strength of prevailing winds during January—April, precipitation over the Baltic, and melting ice. By careful observation of these factors, either directly or indirectly, forecasts of fishing prospects in the Kattegat have been possible (Jensen, 1939, p. 75). Over the 14-year period 1925—1938 eleven forecasts were reasonably accurate and only three were completely

Table 1.

Sea temperatures and arrival dates: 1945—1953.

Year	Month	Date of Arrival	Sea Temp. °C.	Remarks
1945	May	10	11·6	
1946	„	21	11·6	
1947	„	22	11·6	
1948	„	8	11·6	
1949	„	12	12·2	Sea Temp. 11·6°C. on 11. May.
1950	„	7	11·1	Sea Temp. 11·6°C. on 8. May.
1951	„	21	11·1	Sea Temp. 11·6°C. on 22. May.
1952	„	11	11·6	
1953	„	10	11·6	
Mean Sea Temperature on Date of Arrival			11·6	

wrong. L u m b y (1923) failed to find any correlation between catches of mackerel and surface temperatures *in situ* in the spring mackerel fishery off the coasts of Cornwall in 1922 but he was unable to obtain adequate data upon which any firm conclusions could be based.

It has constantly been observed by anglers that the arrival of mackerel close inshore in the Torbay (Devonshire) area occurs fairly regularly about mid-May and that their subsequent departure for deeper water takes place somewhat less regularly in late autumn, mainly in October. Following upon these generalized observations, more precise records have been kept of arrival dates over the 9-year period 1945—1953 inclusive, and of departure dates over the 13-year period 1941—1953 inclusive. All these arrival and departure records were determined by the dates on which the first and last fishes were caught by rod and line within the area. The observations are regarded as reliable, having been made by one of ourselves (L. A. J. J.) and certain other anglers of dependability. Over the periods involved fishing always began in late April, before any mackerel had arrived, and continued for at least three weeks after the date of the last recorded catch.

The records reveal a close correlation with sea surface temperatures as made by the Torquay Meteorological Office 100 yards from the shore, 1 foot below the surface, in water having a mean depth of 14 feet. These temperatures are not significantly affected by the state of the tide.

It will be seen in Table 1 that, with one exception, mackerel made their first appearance close inshore when the sea temperature was within the range of 11·1—11·6°C. In six different years the temperature was exactly 11·6°C., and on those occasions when it differed a reading of 11·6°C. was made either one day before or one day after the recorded appearance of the fish. For comparative purposes the mean weekly temperatures for periods of four weeks before, and four weeks after, the arrival dates are given in Table 2. While too much emphasis must not be placed on the exact value of 11·6°C. it is nevertheless clear that

Table 2.

Mean weekly temperatures (°C.) over periods of four weeks before, and four weeks after, arrival dates, and temperature on date of arrival.

	Before				Arrival Date	After			
	4	3	2	1		1	2	3	4
1945	11·1	12·2[1])	11·1	10·4	*11·6*	12·2	12·8	12·8	12·8
1946	10·3	11·1	11·6[2])	11·3	*11·6*	12·2	12·2	13·3	12·8
1947	8·5	9·4	10·6	10·6	*11·6*	12·2	13·3	12·2	13·3
1948	9·4	10·6	10·6	10·6	*11·6*	12·2	13·6	13·0	12·8
1949	10·9	10·6	10·9	11·3	*12·2*	12·5	12·8	12·6	13·3
1950	10·0	9·4	9·4	10·9	*11·1*	12·2	12·6	13·0	13·3
1951	9·7	9·7	9·5	10·6	*11·1*	11·6	12·2	14·1	13·3
1952	9·4	10·0	10·8	11·1	*11·6*	11·4	13·3	13·1	13·1
1953	8·3	9·9	9·7	11·3	*11·6*	12·5	12·0	12·0	12·4
Means	9·7	10·3	10·5	10·9	*11·6*	12·1	12·8	12·9	13·0

[1]) Strong S.E. to E. winds during the week caused a heavy shore swell (*vide* p. 68).
[2]) N.N.E. winds caused a heavy shore swell.

Table 3.

Sea temperatures and departure dates: 1941—1953.

Year	Month	Date of Departure	Sea Temp. °C.	Remarks
1941	October	20	13·9	
1942	„	21	12·2	
1943	„	17	13·9	
1944	„	2	13·3	2nd coldest October for period (mean sea temp. for month, 13·0°C.).
1945	„	22	15·0	Mackerel driven out by ground-swell which lasted until 27th when sea temp. was 13·3°C. The fish did not return.
1946	„	23	12·8	
1947	„	27	12·8	
1948	„	24	12·2	
1949	November	11	12·2	Warmest October for period (mean sea temp. for month, 16·15°C.).
1950	October	10	12·8	3rd coldest October for period (mean sea temp. for month, 13·5°C.).
1951	„	30	12·8	
1952	September	24	13·9	Coldest September for period[2]) (mean temp. for month, 14·6°C.).
1953	November	4	12·2	
Mean Sea Temperature on Date of Departure			12·9[1])	

[1]) This excludes 1945.
[2]) Followed by coldest October for period (mean, 12·5°C.).

in the weeks before arrival the temperatures are fairly consistently lower than those on arrival dates and quite consistently higher after the arrival dates.

Table 4.

Mean weekly temperatures (°C.) over periods of four weeks before, and four weeks after, departure, and temperature on date of departure.

	Before				Departure Date	After			
	4	3	2	1		1	2	3	4
1941	15·2	14·7	15·2	13·9	*13·9*	13·5	10·9	9·4	10·6
1942	13·9	14·4	13·6	13·3	*12·2*	12·2	11·1	10·6	8·6
1943	15·7	15·0	14·1	15·0	*13·9*	13·3	13·3	13·0	11·6
1944	15·2	15·5	15·5	14·1	*13·3*	13·3	13·3	12·8	11·6
1945	16·0	16·6	15·2	15·2	*15·0*	14·2	14·1	13·0	11·3
1946	15·2	15·0	13·9	13·3	*12·8*	12·5	11·4	11·1	10·6
1947	15·7	15·7	15·2	14·4	*12·8*	12·8	13·3	12·8	12·2
1948	15·5	15·0	14·7	13·3	*12·2*	11·9	11·9	11·6	11·9
1949	16·3	14·1	12·2	12·2	*12·2*	11·9	11·9	11·1	11·1
1950	15·0	13·9	14·4	13·6	*12·8*	14·1	13·3	12·5	11·1
1951	14·7	14·1	13·3	12·8	*12·8*	12·2	12·5	11·9	11·4
1952	17·1	15·9	14·4	14·1	*13·9*	13·3	12·7	12·6	12·4
1953	14·7	14·1	13·7	12·7	*12·2*	12·3	12·1	11·8	11·5
Means	15·4	14·9	14·2	13·6	*13·1*	12·9	12·3	11·9	11·2

Departure records for the years 1941—1953 inclusive are recorded in Table 3. The range of temperature over the 13-year period, with the exception of 1945, is 12·2—13·9°C. with a mean of 12·9°C. The year 1945 is regarded as exceptional because a prolonged period of easterly winds of Force 6—7 set up a heavy ground-swell that drove the fish off shore on the 22. October when the temperature was 15°C. Although temperature conditions were still favourable when the swell abated on 27. October, the fish did not return. Even at the height of the mackerel season an easterly "blow" causes the mackerel to move off shore and several days normally elapse after it subsides before the fish re-appear in shallow water. For comparative purposes the mean weekly temperatures for periods of four weeks before, and four weeks after, the departure dates are given in Table 4. Here again it will be seen that the temperatures are consistently higher before the departure dates and fairly consistently lower after them.

Some records of sea temperatures in the offshore mackerel spawning centres were made by C o r b i n (1947, p. 83) during mackerel investigation cruises in the periods 12.—20. April 1937, 7.—18. April 1938, 16.—27. April 1939, 31. May—7. June 1939, and 20.—22. July 1938. Temperature ranges in the top 25 metres of water were found to be:—

April 1937	10·30—10·62°C.	Mean 10·50°C.	(4)[1])
„ 1938	9·95—11·12	„ 10·27	(12)
„ 1939	10·49—12·30	„ 11·44	(14)
May—June 1939	13·22—15·42	„ 14·63	(7)
July 1938	14·16—16·30	„ 15·52	(4)

Extreme range, all cruises, 9·95—16·30°C.

[1]) The numbers of stations from which the means have been calculated are shown in parentheses.

Table 5.

Sea temperatures (°C.) at International Station E1 (surface and 70 m.) and in Torbay on day of arrival, and mean weekly temperatures during four weeks before, and four weeks after, arrival.

Italics indicate a well marked thermocline.

Year	Station and Depth	Weeks before				Arrival Date and Sea Temp.	Weeks after			
		4	3	2	1		1	2	3	4
						22. May				
1947	E1 Sur.	*10·4*	*10·7*	*11·0*	*11·4*	*11·7*	*12·1*	*12·5*	*13·0*	*13·6*
	E1 70 m.	*9·0*	*9·1*	*9·3*	*9·5*	*9·6*	*9·9*	*10·0*	*10·3*	*10·6*
	Torbay	8·5	9·4	10·6	10·6	11·6	12·2	13·3	12·2	13·3
						8. May				
1948	E1 Sur.	*10·1*	*10·5*	*11·0*	*11·4*	*11·8*	*12·2*	*12·2*	*12·2*	*12·3*
	E1 70 m.	*9·1*	*9·4*	*9·7*	*10·0*	*10·8*	*10·6*	*10·8*	*10·9*	*11·0*
	Torbay	9·4	10·6	10·6	10·6	11·6	12·2	13·6	13·0	12·8
						12. May				
1949	E1 Sur.	9·8	10·4	*10·8*	*11·3*	*11·7*	*12·2*	*12·7*	*13·3*	*13·9*
	E1 70 m.	9·8	10·0	*10·2*	*10·2*	*10·4*	*10·6*	*10·8*	*11·2*	*11·4*
	Torbay	10·9	10·6	10·9	11·3	12·2	12·5	12·8	12·6	13·3
						7. May				
1950	E1 Sur.	10·5	10·2	10·7	10·8	*11·0*	*11·4*	*11·7*	*12·8*	*13·4*
	E1 70 m.	10·2	10·2	10·3	10·4	*10·5*	*10·7*	*10·8*	*11·1*	*11·4*
	Torbay	10·0	9·4	9·4	10·9	11·1	12·2	12·6	13·0	13·3
						21. May				
1951	E1 Sur.	*9·7*	*10·0*	*10·2*	*10·5*	*10·8*	*11·5*	*12·0*	*12·5*	*13·2*
	E1 70 m.	*9·0*	*9·1*	*9·4*	*9·5*	*9·8*	*10·0*	*10·4*	*10·5*	*10·7*
	Torbay	9·7	9·7	9·5	10·6	11·1	11·6	12·2	14·1	13·3
						11. May				
1952	E1 Sur.	9·8	*10·3*	*10·7*	*11·1*	*11·5*	*11·9*	*12·5*	*13·1*	*13·7*
	E1 70 m.	9·4	*9·5*	*9·6*	*10·8*	*10·0*	*10·2*	*10·4*	*10·6*	*10·9*
	Torbay	9·4	10·0	10·8	11·1	11·6	11·4	13·3	13·1	13·1
						10. May				
1953	E1 Sur.	8·7	8·9	9·2	*9·7*	*10·2*	*11·0*	*11·6*	*12·2*	*12·9*
	E1 70 m.	8·6	8·8	8·9	*9·0*	*9·2*	*9·5*	*9·6*	*10·1*	*10·4*
	Torbay	8·3	9·9	9·7	11·3	11·6	12·5	12·0	12·0	12·4

No temperature records on the spawning centres are available for any of the years covered by the Torbay observations. Nevertheless, it can safely be assumed that the overall temperature conditions were not radically different from those of 1937—1939. This being so, the range of temperature that mackerel encounter in their spawning areas throughout their long-drawn-out spawning season (*vide* Steven, 1949, p. 563) is so considerable as to provide no explanation of the restricted temperature ranges that appear to regulate their arrival and departure in the Torbay area.

Sette (1950, p. 292) states that along the Atlantic coast of North America "temperature has a limiting rather than a causal influence on

Table 6.

Sea temperatures (°C.) at International Station E_1 (surface and 70 m.) and in Torbay on day of departure, and mean weekly temperatures during four weeks before, and four weeks after, departure.

Italics indicate an isothermal water column.

Year	Station and Depth	Weeks before				Departure Date and Sea Temp.	Weeks after			
		4	3	2	1		1	2	3	4
						27. Oct.				
1947	E_1 Sur.	15·7	15·5	15·2	15·0	14·7	14·5	*14·3*	*13·7*	*13·4*
	E_1 70 m.	14·0	14·0	14·1	14·1	14·2	14·2	*14·3*	*13·7*	*13·4*
	Torbay	15·7	15·7	15·2	14·4	12·8	12·8	13·3	12·8	12·2
						24. Oct.				
1948	E_1 Sur.	15·5	15·2	14·8	14·6	14·4	*14·2*	*14·0*	*13·8*	*13·5*
	E_1 70 m.	14·0	14·3	14·5	14·4	14·3	*14·2*	*14·0*	*13·8*	*13·5*
	Torbay	15·5	15·0	14·7	13·3	12·2	11·9	11·9	11·6	11·9
						11. Nov.				
1949	E_1 Sur.	15·9	15·4	14·9	14·3	*13·8*	*13·4*	*12·8*	*12·4*	*12·0*
	E_1 70 m.	15·5	15·1	14·6	14·2	*13·8*	*13·4*	*12·8*	*12·4*	*12·0*
	Torbay	16·3	14·1	12·2	12·2	12·2	11·9	11·9	11·1	11·1
						10. Oct.				
1950	E_1 Sur.	15·2	15·0	14·7	14·5	14·3	14·1	*13·7*	*13·0*	*12·2*
	E_1 70 m.	13·9	14·1	14·1	14·1	14·0	14·0	*13·7*	*13·0*	*12·2*
	Torbay	15·0	13·9	14·4	13·6	12·8	14·1	13·3	12·5	11·1
						30. Oct.				
1951	E_1 Sur.	14·3	14·1	13·8	*13·6*	*13·4*	*13·2*	*13·0*	*12·7*	*12·4*
	E_1 70 m.	13·3	13·4	13·5	*13·6*	*13·4*	*13·2*	*13·0*	*12·7*	*12·4*
	Torbay	14·7	14·1	13·3	12·8	12·8	12·2	12·5	11·9	11·4
						24. Sept.				
1952	E_1 Sur.	15·6	15·6	15·2	15·0	14·7	14·5	14·1	13·8	*13·4*
	E_1 70 m.	12·9	13·3	13·7	14·0	14·2	14·0	13·9	13·7	*13·4*
	Torbay	17·1	15·9	14·4	14·1	13·9	13·3	12·7	12·6	12·4
						4. Nov.				
1953	E_1 Sur.	14·2	14·4	14·5	14·1	*13·6*	*13·2*	*12·8*	*12·7*	*12·7*
	E_1 70 m.	13·7	14·1	14·5	14·0	*13·6*	*13·2*	*12·8*	*12·7*	*12·7*
	Torbay	14·7	14·1	13·7	12·7	12·2	12·3	12·1	11·8	11·5

the appearance of mackerel". Mackerel will not arrive in a locality unless the temperature be suitable, but a suitable temperature does not necessarily mean the immediate arrival of mackerel. The same is probably true everywhere but with different limiting temperatures in widely separated localities.

The temperatures at E_1 — an international hydrographical station[1]) at which regular monthly temperature readings have been taken for very many years — have also been examined. Temperatures were not

[1]) 50°02'N., 04°22'W. — about 10 miles to seaward of Eddystone Lighthouse and about 40 miles from Torbay.

always available for E_1, for the same day that mackerel arrivals at Torquay were recorded; these have been obtained by interpolation, but the error introduced, if any, will be negligible.

There is no close connexion with the E_1 temperatures. Nevertheless, the results are of some interest even if they cannot be interpreted. In Table 5 the arrival dates and the temperatures at Torbay are shown together with the temperatures at E_1 at the surface and at 70 metres, which is near bottom. The approximate mean temperatures at E_1 in each of the four weeks before and after arrival are also given. It will be seen that in no year did the fish arrive before a well marked thermocline had formed at E_1. In some instances the thermocline had formed at least a month earlier; in others only a week or so — but it had always formed.

Conversely, on departure, the thermocline at E_1 had almost always broken down completely, or nearly completely, as shown in Table 6.

Whether or not thermocline formation and breakdown are correlated in any way with the mackerel movements is not known. It may be that they are merely phenomena which happen at about the same time without being in any way connected. Nevertheless, the fact is worth noting and will be more closely observed, it is hoped, in future years.

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Letter to the Editor.

A Temperature-Salinity-Depth Recorder.

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Commonwealth Scientific and
Industrial Research Organization,
City Road,
Chippendale. N. S. W. Australia.
20th January, 1955.

The Editor,
Journal du Conseil International pour
l'Exploration de la Mer.

Dear Sir,

During a recent visit overseas, the design of a temperature-salinity-depth recorder being developed in this laboratory was discussed with a number of people. As there appeared to be considerable interest in this problem, and as a review of the use of conductivity for the measurement of salinity was being prepared for publication in the *Journal du Conseil*, it was suggested that a brief preliminary description of the recorder might be published.

The recorder has been designed with the following ranges and accuracies:—

Temperature: 0° to 30°C., ±0·1°
Chlorinity: 18·3 to 20·5 ‰, ±0·03
(Corresponding to Salinity 33 to 37 ‰, ±0·05)
Depth: 0 to 1,000 metres, ±20 m.

The instrument consists of an underwater unit and a shipboard unit. The underwater unit weighs 130 lb. in air, 100 lb. in water, and has an overall length of about 30 ins. It is suspended by a single-conductor armoured cable (0·182 ins. diameter, 2,700 lb. breaking strain, manufactured by American Steel and Wire Co.). The single insulated conductor carries electrical power down to the underwater unit, and at the same time signals representing the measured quantities pass up the cable to the shipboard unit.

The underwater unit contains an oscillator whose frequency depends on the ratio of two resistances in adjacent arms of a bridge network (see

G. E. Stastny and R. S. Butts, "Strain-gage Remote Metering", Tele Tech., March 1953, p. 73). By switching in different combinations of measuring elements and fixed resistors, the one oscillator is made to transmit sequentially information on chlorinity, temperature, and depth, as well as two "reference" frequencies. In the shipboard unit, the frequencies are converted to D.C. potentials and recorded on a potentiometric strip-chart recorder. Each quantity is recorded for 6 seconds, so that a complete switching sequence (three measured quantities and two reference quantities) takes 30 seconds.

The temperature measuring element is a thermistor (Standard Telephones and Cables Pty. Ltd., Type F). Chlorinity is measured by a conductivity cell with platinized platinum electrodes. The effect of temperature on conductivity is compensated by means of a thermistor, with fixed resistors in series and in parallel, connected in a bridge arm adjacent to the conductivity cell.[1]) The compensation is such that the error due to lack of exact compensation is less than $\pm$ 0·03 $^0/_{00}$ of chlorinity in the temperature range 5° to 30°C. A temperature correction is necessary below 5°C. A small correction for the effect of pressure on conductivity is also necessary.

Pressure is measured by a pressure transducer consisting of a Bourdon tube actuating a small potentiometer (Type 548, manufactured by J. Langham Thompson, England). The accuracy of this unit ($\pm$ 2 $^0/_0$ of full scale) may lead to unacceptable errors in the first hundred metres below the surface, and it may be necessary to get depths in this range from a meter-wheel.

A winch fitted with a slip-ring is used. Since there is only one insulated conductor the slip-ring can be of simple design. Slip-ring contact conditions are not critical, since the signals are frequencies and not magnitudes. It is planned to lower the underwater unit at a uniform rate of about 100 metres/minute, so that each quantity is recorded at intervals of about 50 metres. The recording process is continuous while the instrument is being raised or lowered. Near the surface and near the thermocline, more detail can be obtained by lowering or raising more slowly.

The instrument has been completed except for the winch drum and slip-ring. Laboratory tests have shown the need to modify the switching mechanism in the underwater unit. It is hoped that the equipment will be tested at sea within the next few months.

B. V. Hamon.

[1]) An instrument employing a similar compensation circuit has been described recently by A. R. Dorrestein (Kon. Nederl. Meteor. Inst., Medd. en Verhandl., 59, pp. 387—403, 1954).

Reviews.

R. L. Cloet. "Sandwaves in the Southern North Sea and the Persian Gulf". Journ. Inst. Navigation, **7**, 3. London, 1954.

A. H. W. Robinson and **R. L. Cloet.** "Coastal Evolution in Sandwich Bay". Proc. Geologists' Assoc., **64**, pt. 2, pp. 69—82. London, 1953.

R. L. Cloet. "Hydrographical Analysis of the Goodwin Sands and the Brake Bank". Geographical Journ., **120**, pt. 2, pp. 203—215, 7 figs. London, 1954.

A wealth of data on the morphology of the sea floor and on the changes which have taken place between successive surveys lies buried in the archives of Hydrographic Offices or is available on charts but remains unused.

The three papers cited above together demonstrate the valuable use that can be made of this material to understand the processes on foreshore and beach. The first of the above papers deals with megaripples off Sandwich Bay and in the approaches to Bahrein, and seeks to establish their relation to systems of ebb- and flood-channels. It is left to the reader to compare current velocities in knots to G i l b e r t's "first and second critical point". The second paper relates to the inner Stonar shingle bank and an overlapping outer spit. The plausible explanation is offered that the former moved in under the influence of wave action. The Brake Bank off shore is shown to have undergone a similar shift in the last half-century. The gradual northward growth of the spit is demonstrated from its structure and is attributed by the writers to beach drifting.

The third paper deals with the submarine morphology of the same area. By an interesting method C l o e t establishes the probable topography of the chalk buried below the sand banks. Here again the author successfully applies the ideas on ebb- and flood-channels put forward by v a n V e e n. It is a pity the author has not captioned his illustrations and that he cites a long outdated publication from 1906 as the authority on the history of the Flanders coast (see Geologie en Mijnbouw, 1954, p. 201).

It is to be hoped that the writers will continue their valuable studies.

Ph. H. K.

G. Dietrich. "Oceanographisch-meteorologische Einflüsse auf Wasserstandsänderungen des Meeres am Beispiel der Pegelbeobachtungen von Esbjerg". Die Küste, **2**, 2, S. 130—156, Abb. 10. Heide/Holst., 1954.

The principal aim of the paper is to determine the influence of the main oceanographic-meteorological factors upon sea-level variations at Esbjerg. The principal factors are the piling-up of the water by the wind (Windstau), the effects of atmospheric pressure, and the fluctuations in the density of sea

water. But besides his comprehensive investigation of these three elements, the author has made a detailed survey of other factors which influence sea-level. The systematic summary is most instructive, especially as it is furnished with numerical examples which illustrate clearly the quantitative significance of the different factors.

The factors recognized as disturbing sea-level and considered in the paper are nine in all. Some of them, however, seem to be rather insignificant. Thus the alterations of the ocean's topography and the variation in the effect of friction which arises from a modification of the coastal zone, may, as a rule, be neglected. The author shows, moreover, by a numerical example that the dynamic effects of wind-produced currents and of the slope of the sea surface caused by the Coriolis force are relatively slight. The astronomical effect is discussed only in so far it concerns the semi-annual, the annual, and the 18·6-year tides. Shorter waves are of course of no importance, as the author operates only with monthly and yearly averages. An important group comprises the upheaval of the coast and related factors which may influence the yearly sea-level averages to a considerable extent for fairly prolonged periods. The same is valid for the eustatic effect. This factor has, however, not so far been studied enough to give definite results. The values obtained by different authors vary from 0·28 mm. to 1·1 mm. per year; the latter figure, given by Gutenberg, seems to be the most reliable.

Passing over to the three main factors, we note at once that they are discussed in the paper with considerable care. It is evident, however, that the determination of the effect of these factors from the available data is a difficult task and the results must therefore be considered as more or less approximate. The author gives for a period of 102 years (1849—1950) the mean monthly and yearly averages of the direction and velocity of the wind in the vicinity of Esbjerg and the yearly effect of the piling-up of water by wind, the effect of the density, and that of the atmospheric pressure. A few numerical examples may be quoted to illustrate the importance of these factors. The magnitude of the piling-up effect varies between 0·6 and 22·8 cm. The density effect is considerably less, lying between the limits —1·7 and 0·7 cm., and, finally, the effect of atmospheric pressure is rather larger than this, the extreme values being —4·2 and 2·6 cm. Elimination of these factors causes the dispersion of the yearly averages of the sea-level to fall from $\pm$4·7 cm. to $\pm$1·5 cm. Apart from a general increase of sea-level of 1·14 $\pm$ 0·28 mm. per year this dispersion may be due to the influence of the less important factors mentioned by the author, to some degree perhaps also to the effect of other elements, such as precipitation, evaporation, etc. The general increase noted in sea-level seems to correspond surprisingly closely to the value of the eustatic rise stated by Gutenberg. The author points out, however, that the considerable uncertainty characteristic in the eustatic researches makes it impossible to distinguish between the shares of the eustatic factor and of the sinking of the land, in producing the total increase of sea-level at Esbjerg.

E. Lisitzin.

G. Koopman. "Entstehung und Verbreitung von Divergenzen in der oberflächennahen Wasserbewegung der antarktischen Gewässer". Deutsch. Hydrogr. Zeitschr., Ergänzungsh. 2, S. 1—38, Abb. 19. Hamburg, 1953.

Detailed information about the winds over the Southern Ocean is too scarce for correlation with the oceanographic boundaries and Dr. Koopman has to fall back on what is known of the atmospheric pressure distribution. Using a table prepared by A. Assur (1951), he calculates the probable

winds and drift currents and shows that there is good agreement between the calculations and the positions of the convergences and divergences as indicated by the temperature and salinity distributions. The basic facts are that the steepest atmospheric pressure gradient occurs near the Antarctic Convergence, a secondary weakening of the gradient near the Subtropical Convergence, and a change in sign of the gradient where the oceanographic data indicate a change from west- to east-wind drift. The agreement is not perfect, and some of the basic information founded on too few observations, but there can be little doubt that it shows a close association between the oceanographic and meteorological phenomena.

Dr. Koopman is convinced that the Antarctic Convergence is due to the convergence of water transport produced by the steepening of the pressure and wind gradients, but without a more comprehensive numerical treatment of the water circulation and interaction of the ocean and atmosphere his representation may prove no more convincing than the oversimplified thermodynamic explanation which the reviewer put forward some twenty years ago. The steepness of the pressure gradient near the Antarctic Convergence may prove to be related to the north-to-south temperature gradient as well as to the balance between polar, subpolar, and subtropical air masses, and the winds associated with the gradient may affect the water movements and temperature distribution near the surface by their influence on the density layering of the deep and bottom waters as much as by differences in the northward transport of pure drift currents at the surface. It is interesting to note that the author's figures for convergence in the drift currents lead to the conclusion that most antarctic water sinks in the eastern Atlantic and western Indian oceans, which is contrary to the indications given by the salinity distribution in the Antarctic Intermediate Current (Deacon, 1937, p. 68). It may prove very difficult to explain the small change in pressure gradient near the Subtropical Convergence without taking account of the changes in conduction and evaporation due to differences of water temperature and salinity across the convergence.

The author makes an interesting study of the Weddell Sea Current spreading eastwards across the Atlantic Ocean towards Bouvet Island, and of the westward movement farther south, which he calls the "Weddell Counter Current". Here too there is evidence of associated meteorological conditions, but the reasoning about the variations in the two movements is based mainly on variations in the temperature and salinity distributions. It is shown that a high silicate content in the surface water can be used as evidence of upwelling.

The work is based almost entirely on the observations made during the "Discovery" investigations; it shows that these observations provide a basic picture which hangs together however it is approached, and except for actual measurements or reliable estimates of the velocities of the deep-water movements there is sufficient material to encourage more penetrating applications of theoretical fluid dynamics to the problems of the wind-driven and thermodynamic circulation. By his demonstration of the close association between the meteorological and oceanographic features Dr. Koopman will undoubtedly stimulate fresh interest in these problems.

G. E. R. D.

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R. Bainbridge. "Studies on the Interrelationships of Zooplankton and Phytoplankton". Journ. Mar. Biol. Assoc. U. K., **32**, 2, pp. 385—447, 4 figs. + 1 pl. Cambridge, 1953.

The paper presents the results of an extensive experimental attempt at solving the problem of the relative abundance of phyto- and zoo-plankton in restricted water masses. The two theories regarding factors operating to produce an inverse quantitative distribution of animal and plant plankton, namely, the grazing theory, introduced by H a r v e y, and the animal exclusion theory of A. C. H a r d y, form the starting point both for experimental studies and also for the theoretical considerations.

Special apparatus constructed of Perspex is described for studying the behaviour of zooplankton in "horizontal" and "vertical" experiments. In the "horizontal" experiments various zooplankton species were shown to migrate into concentrations of the diatoms *Sceletonema costatum*, *Thalassiosira nordenskioldi*, *Biddulphia sinensis*, and *Nitzschia closterium*, each in uni-algal cultures, and also into mixed diatom populations. Similar results were obtained for the flagellates *Chlamydomonas* sp., *Dicrateria* sp., *Oxyrrhis* sp., and *Peridinium trochoideum*, while no reaction was recorded in the case of the diatoms *Lauderia borealis*, *Coscinodiscus concinnus*, and *Eucampia zoodiacus*, or with the flagellates *Exuviaella baltica* and *Syracosphaera carterae*. For two flagellates *Rhodomonas* sp. and *Gymnodinium* II, a migration away from the concentration of phytoplankton was observed. These results were all obtained with mysids. The positive migrations are interpreted as taking place for the purpose of feeding, and it is thought likely that sometimes the effect of the phytoplankton may be conveyed by substances dissolved in the water, probably of an organic nature.

The flagellates which invoke an avoiding reaction in the zooplankton "almost certainly do so through some substance dissolved in the water". The evident "toxicity" of these flagellates was demonstrated in a great number of toxicity experiments with 68 different uni-algal cultures of phytoplankton. Of these, five gave results which clearly indicated that they had toxic properties of some kind. These included *Gymnodinium* II, which the zooplankton avoided in the horizontal experiments.

Negative migration was also recorded when dense bacteria cultures were used, while ammonia produced a positive migration.

The results obtained with *Artemia salina*, decapod larvae, and small copepods were not as consistent as those with mysids, but many showed a similar trend. Forty-seven experiments with *Calanus finmarchicus* and various diatoms and flagellates gave, however, very variable results and the conclusion is drawn that in the horizontal experiments, *Calanus* does not show any significant migration in relation to the various phytoplankton organisms used.

On the other hand, 113 experiments for testing the vertical movement of *Calanus finmarchicus* in water enriched with uni-algal or mixed cultures of various phytoplankton species and in filtered water showed that in all cases except with Flagellate I and *Chlorella stigmatophora* more *Calanus* swam upwards when phytoplankton was present than when absent. A few experiments with young *Hemimysis lamornae* showed that more animals swam upwards in water enriched with *Chlamydomonas* sp. and with *Sceletonema costatum* than in filtered water, while decapod larvae and young *Thysanoessa inermis* seemed to be unaffected by the presence of phytoplankton.

The differing reactions of *Calanus* in the horizontal and vertical experiments are considered to be due to the tendency of this species to swim in a vertical plane, whereas the various mysids and *Artemia* make excursions in

both horizontal and vertical directions. The small copepods showed random movements.

Although the author stresses the point that the experimental results should only be applied with the greatest diffidence to the problems found in nature itself, underwater observations confirm that the behaviour of the animals under experimental conditions is essentially the same as it is in the sea.

The evidence obtained from these experiments indicates that the hypothesis of animal exclusion cannot be of such universal application as was originally believed, since an excluding effect was restricted to fairly high concentrations of two flagellate species which are not known to be important members of natural populations in the sea.

The author discusses the effect on the relative zooplankton and phytoplankton distributions of migration and grazing of zooplankton and of the growth of phytoplankton, with the point in view of explaining the somewhat inconsistent observations of the relative abundance of these two components of the plankton in various waters. His considerations are of general interest, and it would seem most desirable to test them on suitable material by experiments in which modern quantitative methods for phytoplankton and zooplankton studies were combined with detailed hydrographic and hydrochemical observations.

The investigation is a fine illustration of what can be obtained through an experimental approach to marine ecological problems and at the same time, it reveals the scantiness of reliable information on the distribution of the various components of marine plankton populations.

T. B.

A. C. Hardy, and **R. Bainbridge.** "Experimental observations on the vertical migration of plankton animals". Journ. Mar. Biol. Assoc. U. K., **33**, 2, pp. 409—48, 29 figs. Cambridge, 1954.

The vertical migration of plankton animals has been studied for many years, mostly by means of nets used at different levels in the sea and at different times of the day and night. There has also been some experimental work on vertical migration both in the sea and in the laboratory, but no direct observations had been made of the actual movements of the plankton animals.

The authors have constructed a very ingenious apparatus in which it is possible to observe directly the vertical movements of plankton animals, swimming in an endless column of water. A description of the experimental gear referred to in the paper reviewed has been published earlier, together with some of the results. (Hardy, A. C., and Bainbridge, R., 1951. "Vertical migration of plankton animals". Nature, Lond., **168**, pp. 327—8).

The apparatus consists of a curved transparent tube of Perspex 2 × 1½ in. cross-section, bent to form a complete circle 4 ft. in diameter and mounted vertically, so that it can be rotated like a wheel. The tube is filled with water and the animals introduced through a lid which is afterwards closed. Then the wheel is turned so that the animal is halfway up one side. It may move up or down quite freely, and as it moves, the wheel can be rotated by hand in order to keep the animal in the same position. Inside the tube small doors equipped with weights or floats ensure that the water turns with the wheel. The doors always remain open on the observer's side and closed on the opposite side.

All the movements of the wheel can be recorded by means of an electric kymograph. The apparatus was mounted in a small glass-house especially built for the purpose, the walls of which were covered with different thicknesses of paper to give a graded light from above, and the intensity of the

light as a whole could be varied by a series of sheets which could be drawn over the roof and sides.

Compared with conditions in the sea, the apparatus has certain limitations. The pressure does not change when the animal is swimming, nor is there any gradual change in light intensity, although the effect may be roughly produced by adjusting the screens overhead or by varying the artificial illumination.

About fifty experiments were carried out with plankton animals of different species, under varying conditions of light, and selected experiments have been described in detail. Different types of vertical movements could be distinguished. The larger copepods, such as *Calanus, Labidocera,* and *Temora* swim up and down steadily, but they may also progress with a "hop-and-sink" movement, when short bursts of upward swimming alternate with periods of passive sinking. Downward migrations are almost invariably accomplished by swimming head-first, interrupted only exceptionally by passive sinking. Smaller copepods move more unevenly, and follow a zig-zag path, but with the resultant movement either up or down. Euphausiids, decapod larvae, and the copepod *Euchaeta* often make straight up-and-down movements of great length and at high speed, but they also swim horizontally into the sides of the tube. Underwater observations by Bainbridge confirmed that the types of movement observed in the apparatus were of the same kind as those occurring in the sea, and that the tube had no "canalizing" effect which made the behaviour of the animal in the wheel unnatural.

The distances travelled and the speeds of vertical swimming over different periods of time are given for various plankton animals. It is interesting that in 2 minutes *Calanus finmarchicus* may swim upwards at a speed of 66 m. per hour and downwards at 107 m. per hour, while for longer periods the speeds are 15 and 47 m./h. respectively. This implies that in the sea a diurnal vertical migration of 100 or 200 m. up and down is quite feasible. Euphausiids move very rapidly; *Meganyctiphanes* travels at about 130 m./h. for fairly long periods and 215 m./h. for short periods.

Such small creatures as *Balanus* nauplii moved at a remarkable speed, 15 m./h. for long and 23 m./h. for short periods.

As regards reactions to light, there were great differences in behaviour from one individual to another, even within the same species, and the same individual, even, was found to react differently under apparently identical conditions. With a few exceptions, however, all the animals tested exhibited a negative reaction to strong light and swam downwards and away from it very rapidly. On most, but not all, occasions a definite positive migration took place towards the source of low light intensities. The removal of all light during daytime did not evoke an upward movement on most occasions, and it is therefore clear that there is not a negative geotaxis which comes into play in the absence of the inhibiting effect of strong light. Marked alterations in light intensity in the morning had no effect on the behaviour of *Daphnia,* whereas in the afternoon complete blackout caused the same specimen to swim rapidly upwards on two occasions.

The temperature of the water in the experimental tube is not mentioned by the authors. It is to be expected that the experimental conditions, e. g., absence of variation in salinity, pressure, temperature, and also, possibly, lack of food may have an effect on the animal's reaction to light. The sudden change in environment from the sea to the apparatus may also affect the reactions of the animals. Internal factors connected with the development of the animals may gradually change the reaction to light, and the change may be speeded up by the experimental conditions. It has also been shown

by earlier workers that the behaviour of *Calanus* changes with prolonged captivity. The authors were aware of these matters, and the animals were used for the experiments as soon as possible after capture. They stress that the experiments must necessarily be regarded as preliminary.

The paper adds considerably to our knowledge of the vertical migrations of plankton animals — especially with regard to the manner of movement, and the speed and duration of migrations — and also of their reactions to light. We may therefore hope that further experiments will be carried out to elucidate further these very interesting and important problems.

Kr. Fr. W.

H. Bohl. "Die Verbreitung der Schollenbrut in der südlichen Nordsee im März 1953 in ihrer Abhängigkeit von der hydrographischen Situation". Kurze Mitt. Inst. Fischereibiol. Univ. Hamburg, Nr. 4, April 1954, S. 18—37, Abb. 2. Hamburg, 1954.

While a very considerable amount of quantitative work has been done on the egg production of the plaice in the southern North Sea, it was not until 1936 that plankton surveys located the not unexpected plaice spawning area between the Dogger Bank and the German Bight. The paper under review presents further data which clearly confirms the earlier findings and adds the interesting observation that the spawning in this area can be of considerable intensity as late as mid-March.

Much of this paper is devoted to a discussion on the relation between the egg production at different positions in the southern North Sea and the contemporary temperature and salinity. Bohl concludes that temperature exercises a decisive influence on the date of spawning ("Die Temperatur besitzt einen entscheidenden Einfluss auf den Zeitpunkt des Laichens."). Simple correlations between limited numbers of observations appear to have led to deductions which on more extensive data cannot be upheld as the whole truth. Extensive data about to be published for the Southern Bight plaice spawning indicate considerable constancy in the time of the start and end of spawning, but variation in the time of peak spawning. When correlated with the temperature in the area at the time of peak spawning and some 3—4 weeks before peak spawning, the time of peak spawning was found to occur early or late in years of above-average temperature, but has not occurred early in years of below-average temperature. Thus, while low temperatures may always delay spawning, the reverse does not appear to hold true.

With regard to salinity Bohl concludes that egg production is highest where salinity is highest ("Es wurde jedoch ausführlich dargelegt, dass die Laichproduktion dort am grössten ist, wo die Scholle einen möglichst hohen Salzgehalt vorfindet."). While there are very many cases in the southern North Sea where high egg counts occur in water of high salinity, there is no proof that this is a causal relationship, and the finding of Bowman (1914) on the east coast of Scotland that his highest densities of plaice eggs occurred in the Moray Firth, where the temperature and salinity were less than further off shore, shows that the correlation is not universally found.

Russell's review of the migrations of fish appears to put the position more satisfactorily when he deduces a contranatant spawning migration which in the southern North Sea inevitably means a movement into water of greater salinity.

There is an interesting discussion on the possibility of the numbers of eggs found in 1953 in the eastern area being inflated as a result of the spawning of abundant 1947 and 1948 year-classes. *A. C. Simpson.*

R. Kändler. "Über das Laichen der Makrele (*Scomber scombrus* L.) in der Kieler Bucht". Kieler Meeresforsch., **10**, 2, S. 182—201, Abb. 8. Kiel, 1954.

The paper opens with a clear historical survey of our knowledge of the biology of the mackerel, especially the maturity stages, spawning grounds, and growth, and also of the methods for age determination. Kändler finds the scales just as good as the otoliths (as also have D. Nilsson, Ehrenbaum, Steven, and Corbin) but stresses the necessity to remove the scales very carefully because they are so loosely attached to the fish.

For 5 years up to 1912 fishing for eggs was carried out in the Belts and western Baltic during June—July but no mackerel eggs were found and only one mackerel larva was taken, in the northern part of the Great Belt. In the Kiel Bay a few mackerel eggs were taken in 1926, and they appeared from 1935 onwards in the regular hauls made at the "Fehmarn" lightvessel during 1934—43. More information about their distribution has been collected on cruises during 1938—39, 1948—49, and 1951—53. The largest number in one haul, 92 per m^2., occurred in 1952. Eggs are regularly found in water of *ca.* 20 ‰ salinity and sometimes at 16 ‰. While some of the eggs might have been transported from more northern waters by the currents, most of the eggs were in the first stages of development, and spawning mackerel have been recorded here since 1948. The eggs are fertilized, develop, and hatch quite normally, and larvae up to 6 mm. in length have been found. The fact that neither older larvae nor young fish have been found in the western Baltic gives Kändler good reason to believe that they cannot survive there. The spawning season is June—July, as it is in the Skagerak and neighbouring waters.

The age of the mackerel in one sample was investigated and was found to be from 2 to 15 years. The length of the 3- to 4-year-old fish was *ca.* 3 cm. greater than that found by Ehrenbaum, and Steven and Corbin. The lengths found by back calculation corresponded fully to the lengths found by David Nilsson and by LeGall, but the reasons for the differences between the two series of lengths and also for the differences from the earlier results await further investigation.

The food of the mackerel in the western Baltic was studied by Kändler and Lühmann. They found that it changes from one year to another. When copepods were abundant, they seemed to be preferred, but otherwise small herring, cod, and *Gobius*, together with *Mysis* and *Crangon*, were the most important foods, occasionally, however, *Diastylis*, which always keeps close to the bottom, constituted the whole or the main part of the stomach contents.

Until 1912 few mackerel came to the western Baltic before August, whereas since 1924 a large fishery has been carried on from July onwards. Now young fish are caught during November, December, and January, together with anchovy and horse mackerel, and their immigration to these waters is due to the stronger ingoing currents of recent years.

The catch has fluctuated widely from one year to another and the increase since 1948 is explained by an increase in the westerly component of the wind.

Many new and important results appear from these detailed investigations, and we may hope that our knowledge may be increased by their continuation.

Aage J. C. Jensen

P. Fr. Meyer. "Die Dampferfischerei in der Ostsee während der Kriegsjahre 1939/45 und ihre Bedeutung für die Fischwirtschaft und Fischereiwissenschaft. Wirtschaftlicher Teil". Ber. Deutsch. Wiss. Komm. f. Meeresforsch. N. F., **12**, 1, S. 1—48, Abb. 12. "(Biologischer Teil I)". Ibid., **12**, 2, S. 168—209, Abb. 13. "(Biologischer Teil II)". Ibid., **12**, 4, S. 457—479, Abb. 7. Stuttgart, 1952.

These papers describe, and comment on, the astonishing results of the German steam-trawler fishery in the Baltic during the war. During 1940—44 this fishery had an annual yield of *ca.* 55 million kg., of which 90—95 % was cod. In addition, the German cutter fishery in the Baltic took some 14—26 million kg. of cod a year, compared with about 7—14 million kg. in 1936—39. It may be mentioned that the total catch of cod in the Baltic (the western Baltic included) from all countries except Russia, Esthonia, and Lithuania in 1940—44 seems to have been 70—100 million kg. a year against 20—40 million kg. during 1936—39.

The first paper explains that during the war the outlook for the employment of the German steam trawlers in useful fishing seemed hopeless, since they were cut off from the grounds which before the war yielded 83 % of the total output of the German fishery. The Skagerak and Kattegat had at one time been fished by steam trawlers, but had been exploited very little during later years, and steam trawlers had never fished in the Baltic, except for a few unsuccessful experiments during the first war, when they took small quantities of flatfish only. In the second war, however, it turned out that steam trawling in the Baltic provided good catches, and Meyer considers that fishery science had underestimated the real character of the Baltic. The decline in the stock of flatfish in this area had been thought to be due to overfishing, but Meyer believes that it was due to the same great natural fluctuation which gave rise to the large stock of cod. Although other authors have, no doubt correctly, attributed the great increase of the stock of cod in the Baltic (and in the Belts) to climatic change, the reviewer cannot agree with the first of these postulates, in view of the many indications of overfishing in the flatfish stocks. It is of value that the influence of climatic changes should be stressed once more.

It is mentioned that Germany set up a scientific control of the development of the fishery and of the stocks, in order that the great experiment should not harm the stock.

The catch per voyage was about twice as great in the period February/March to May/June as in the rest of the year, i.e., it culminated just before and during the cod spawning season in the Baltic. Both monthly catch per voyage and per fishing day are calculated for each main area of the Baltic. Table 7 shows that the catch per voyage in the Baltic in 1939—45 was almost 1½ times greater than that of the bottom trawl fishing in the North Sea in 1937, and that the catch per day at sea and catch per fishing day were almost 10 % higher. Some few figures show that the catch per fishing unit in the North Sea after the war became very much larger than that in the Baltic during the war. Comparisons between the catch per fishing unit for cutters after the war and for steam trawlers show that the density of the cod stock in 1946—48 was at least as high as the average during the war. The catch per fishing day increased from 2·5 to 5·3 tons between 1939 and 1941 and then decreased to *ca.* 4 tons in 1943 and 1944.

A very interesting and detailed account, with maps, is given of the fishing grounds of the steam trawlers in the Skagerak, Kattegat, Belts, and Baltic

for each year, and the average yearly and monthly catch on the different grounds.

The second paper deals with the results of the biological-statistical investigation of the catches. The percentage compositions by species in 305 of the total of 5076 catches in the period September 1939 to December 1943 show that on an average *ca.* 98·5 % of the fish caught were cod, which is somewhat more than the average of 90—95 % given in the first paper. Herring sometimes constituted 30—50 % of the trawler catches especially during the spawning season of the cod, when this fish was of little value, and in a few cases 30—35 % of the catch consisted of flatfish taken in coastal areas. From the catch analyses it is estimated that the steam trawlers landed an average of *ca.* 550 tons of flatfish a year, and even if the true figure was somewhat larger, it is quite certain that this was only a portion of the total German catch of flatfish in the Baltic, which, according to Meyer, p. 172, amounted to *ca.* 4 million kg. a year in 1939—40 and to *ca.* 2 million kg. in 1942—43. Meyer maintains therefore that the steam trawlers did not overfish the stock of flatfish in the Baltic. Some interesting catches of silver eels are also recorded.

The proportions of the market categories of the I-, II-, and III-group cod are given, together with the average catch per steam trawler per voyage and per month. The variation during the year is extremely great, and is explained essentially by the variations in density of the stock which arise from the cod's spawning and feeding migrations. The decrease in the percentage of large cod was enormous, from 64 % in the summer of 1940 to 37 % in the summer of 1943, whereas the percentage of small cod was 6 % in the winter 1939/40, 38 % in the winter 1940/41, and as high as 55 % in the winter 1943/44.

In the Bornholm basin the catch of cod per fishing day was practically the same throughout the years, but in every other part of the Baltic it decreased from 1941 to 1944; in Danzig Bay it fell from 6·3 to 3·2 tons, and in the Gotland basin from 8·0 to 5·6 tons. The catches of flatfish on the grounds fished by the cutters decreased especially (table, p. 172).

Age analyses were carried out on a total of almost 4000 cod from the Baltic, with samples from 43 catches from cutters and 12 from steam trawlers. A few of these were taken by longlines.

The otoliths of the cod are sometimes difficult to read, and the variation of the lengths of the I-group cod in the western Baltic from 26 to 52 cm. must be ascribed to errors of age determination, which must also influence some of the other results. In such a collection of data from the commercial fishery the lengths of the younger age-groups are naturally too high and cannot be compared with the lengths found before the war when fishing was carried out with small-meshed trawls. No doubt the length of each of the older age-groups was a few centimetres less than it was before the war.

In addition some size- and age-distributions are given for catches from the Skagerak and Kattegat during and after the war, and by way of comparison some are given for catches from the Barents Sea after the war also.

The fluctuations which occur in the course of a year in the distribution and density of the stock of cod as a result of spawning and feeding migrations and the yearly cycle in the quality of the cod were studied very closely with regard to their bearing on the fishery. The weight of the fillets, of the sexual organs, and of the liver and the percentage of fat in the liver were investigated in 12 samples distributed over the year. The percentages are illustrated by an instructive graph.

The third paper deals with the stomach contents of the cod in the various

parts of the Baltic. The number of empty cod was found to be astonishingly large, not only on the spawning grounds, where, naturally, it was highest (70 %), but in all parts of the Baltic. In the western parts of the Baltic fish comprised half or more than half of the food taken, but in the Gotland basin, and in one sample from Danzig Bay, *Mysis* and *Idothea* | *Mesidothea entomon* constituted 70 % of the food, and in this case 50 % of the cod were empty.

The main part of the paper describes an investigation of the regional and annual variation in the quality of the cod. The weight length coefficient (k), the percentage weight of the fillets, and the fat content of the liver are on the average, lower in the eastern than in the western Baltic. In three samples, from the Bornholm basin in March, off the Esthonian coast in June, and in Danzig Bay in November, k was 0·75, but 5 other samples from the Bornholm basin gave k between 0·87 and 1·00. In samples from the Oder Bank during the winter months k was 0·9—1·1.

The percentage weight of the fillets decreases with increasing length and age, and the relation of the weight of the head to the total weight increases. These figures are given for each age-group and for the sample as a whole. In view of the uncertainty in the age determinations it might have been better to have calculated them for each length-group in order to show regional differences. Males were more numerous than females on the spawning grounds in spring and summer because the males remain longer on the grounds than the females and because they are, on the average, one year younger than females at first maturity. In every season the males reach maturity before the females, but Meyer finds that most of them finished the spawning before the females. The older cod are the first in the season to spawn.

In conclusion Meyer stresses the importance of natural fluctuations, especially in the Baltic, and emphasizes the fact that the fishing industry should always be ready to exploit the changing possibilities the stock may offer, and argues that cutters of up to 20 m. in length and of 150—180 H. P. would be the most practical for use in the Baltic.

In the chapter entitled "What does the steam-vessel fishery experiment mean to science?" Meyer draws the conclusion that fishing has been of little effect on the stocks, compared with the natural fluctuations in both flatfish and cod. The reviewer would like to stress another principle, which is that a stock of fish in a particular area may yield more than it normally pays to fish, and this may be the case for the stock of cod in the Baltic.

After the war the large trawlers left the Baltic for other and more prolific grounds, and the Baltic stock is now fished only by cutters, which are much cheaper to operate. Naturally the large trawlers found more profitable grounds after the war in areas in which the stock had increased because it had been only lightly fished during the war, but even when the stock has again been thinned on these grounds to the pre-war level or even to less than that, the trawlers have not found it renumerative to go back to the Baltic.

The quantity of fish which can be taken from an area depends also on the possibility of selling the catch, and in pre-war years, when the stock of cod in the Baltic had increased, the catches were sometimes so large that it was difficult to sell the cod landed at Bornholm; landings had sometimes to be stopped because the market could not absorb the catches. Meyer mentions that this occurred in Germany also. After the war filleting and cold storage have helped the sale, but no doubt the catch now corresponds rather closely to what can be sold.

Aage J. C. Jensen.

B. Rasmussen. "On the Geographical Variation in Growth and Sexual Development of the Deep Sea Prawn (*Pandalus borealis* Kr.)". Fiskeridirek. Skr., Ser. Havundersk., **10**. 3. pp. 1—160. 42 figs. Bergen. 1953.

In this very thorough and detailed paper the author greatly extends and amplifies the earlier work of Hjort and Ruud on growth and sex-change in *Pandalus borealis*. The deep-sea prawn is now an important fishery resource in Scandinavian and arctic waters. Although *Pandalus borealis* has been studied fairly extensively in the past, the present work provides yet another example of the need for comprehensive investigations on a regional basis before a sound foundation can be laid for conservation policy.

When Rasmussen began his work it had been found that the biology of *Pandalus borealis*, in relation to growth and the attainment of sexual maturity, was essentially similar in the different areas investigated, viz., Gullmar Fjord, Oslo Fjord, and the Skagerak. The prawns generally matured as males at about 1½ years of age (ca. 90 mm. length) and became functional females at 2½ years (ca. 120 mm.). A few matured as females a year earlier and a few functioned as males for more than one year.

Rasmussen first investigated the prawns of Spitsbergen and found that they grew more slowly and did not mature as males until 3 years old, they continued to function as males in the following year and did not change to females until they were 5 years of age. He began this latest investigation with the intention of making a thorough study of prawns from a great variety of habitats so as to establish the relation between environmental factors and rate of growth and sex-change. Material was collected from numerous stations from southern Norway to Spitsbergen and Jan Mayen. The examination of this large mass of evidence shows that, in general, decreasing sea temperature results in retarded growth and delay in reaching sexual maturity. In certain Norwegian fjords with a shallow bar across the entrance, resulting in lower temperatures and salinities than in the open sea, slow-growing and late-maturing prawn populations were found, similar to those of arctic waters.

The season of spawning and length of the period of egg carriage also vary on the different grounds. In southern Norway spawning takes place in October and November and the eggs hatch about 5 months later. In Spitsbergen and Jan Mayen spawning occurs 3 months earlier and hatching 2 months later, the period of egg carriage being approximately 9 months. In the "threshold" fjords in Norway the conditions are intermediate between those extremes.

The paper includes a description of the prawn grounds in each locality with information on seasons of fishing and hydrology with, in a few cases, notes on the associated fauna. There is also a discussion of the effect of the arctic environment in modifying reproductive patterns.

The bearing of these new discoveries on conservation policies for the prawn fisheries is alluded to only briefly in the two final paragraphs of the paper. There are clearly marked differences in the productivity and rate of replenishment of the stock of prawns at the two ends of its range in Norwegian and arctic waters and no single policy will serve to maintain the fishery in all areas.

Where growth is slow and maturity as females comes late, the danger of local over-fishing must certainly be great, but each area, and in some cases, each fjord, presents a separate problem. No doubt the great body of material available in this paper will be used later as the basis for a discussion of suitable conservation measures.

H. A. Cole.

Current Bibliography.

Prepared by the Editor with the Assistance of Mr. A. R. Margetts.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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